Title: Evaluating the Impact of Fully Autonomous Systems on Hotel Housekeeping Operations: Efficiency, Cost Implications, and Workforce Adaptability

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Abstract:
The hospitality industry is experiencing a paradigm shift with the increasing adoption of Fully Autonomous Systems (FAS) in housekeeping operations. This study explores the feasibility, benefits, and challenges associated with implementing automation in hotel housekeeping. The findings reveal that automation can enhance operational efficiency, reduce human errors, and optimize resource utilization, ultimately leading to improved guest satisfaction. Tasks such as vacuuming, mopping, linen delivery, and digital housekeeping management are identified as the most suitable for automation. However, high initial investment, maintenance costs, training requirements, and privacy concerns are significant barriers to widespread adoption. The study emphasizes that while FAS can streamline housekeeping operations, human involvement remains crucial for maintaining personalized guest experiences. A structured approach to implementation, including upskilling employees and ensuring data security, is necessary to maximize the benefits of automation. Future research should focus on cost-benefit analysis, guest perceptions, and sustainable automation solutions to further refine the adoption of FAS in the hospitality sector. By strategically integrating automation, hotels can improve efficiency, reduce operational costs, and stay competitive in an increasingly technology-driven industry.

Introduction

Fully Autonomous Systems are essentially machines that can operate and make decisions entirely on their own, without needing any human input. Such systems do not require constant supervision or instructions from people. They can sense, and are constantly aware of their surroundings using various sensors and motion sensing technologies, and can subsequently make choices and take actions, all while changing responses and behaviors depending on changing situations and/or unexpected events

For many years in the hospitality landscape, hotels have been at the top of automation levels, with the implementation of keycards and reservation systems. Moreover, with the emergence of robotics, especially in Japan, with the Henn-na hotel in 1999, introduced robotic staff for cleaning and check-in checkout. In 2015, the Yotel Hotel in New York employed the Yobot, a luggage carrying service that still exists to this day. Such are a few strides being taken in the hotel industry towards the implementation of Fully Autonomous Systems, and many more are explored in the literature reviews.

Various Fully Autonomous Systems can be considered viable for the implementation in hotels, especially the housekeeping department, such as delivery robots which can deliver laundry to/from floor back areas, as well as catered towards guest laundry, vacuuming and mopping robots, along with smart dispensing machines for cleaning supplies.

This topic encompasses the integration of Fully Autonomous Systems in the housekeeping department. This topic is highly relevant in today's world with the fast-paced breakthroughs and innovations in the tech industry, and the current Indian hotel industry has not yet taken any significant steps towards implementing such systems in their hotels. In this scenario, a research paper on the same can prove to be highly beneficial to all players in the industry, with hotels being able to analyze the impact of fully autonomous systems in their hotels, while manufacturers can focus their efforts into creating systems specifically catered for the needs of the industry.

The field is fully autonomous systems, and information from the industry-leaders who manufacture and compile software for the same, is crucial in understanding how it works and how it can be implemented efficiently in the hotel industry.

The planning of the entire operation, from the upfront capital cost of installing the machines, to their routine maintenance and the training of both associates and managers, various aspects of the entire operation have to be understood in order to successfully implement the system and its upkeep, all of these and many more points will be briefly discussed in this Research.

Currently available options for Fully Autonomous Systems that can be implemented in hotels are only directed towards the B2C (Business to Consumer) market, with end-point consumers purchasing machines such as robotic vacuum cleaners for their home.

A few examples of these technologies already in play are -

1. Roomba robotic vacuums: They are already in the market, specifically catered towards end consumers and their needs. Launched in 2002, it has been highly successful in its own merit, and roomba's have evolved into a completely autonomous system capable of sweeping, vacuuming and mopping at the same time, with various systems such as lights, LIDAR and Motion Sensing tech that helps the cleaner work efficiently without bumping into anything.

2. Automatic trash segregation systems: Trash segregation has been a challenging feat to accomplish on the hotel's level. With so many different collection points and not enough space sometimes to keep multiple dustbins for segregation of waste in various types, associates have resorted to just piling everything into a single trash-bin and not bothering to segregate, causing harm to the hotel's image with eco-conscious guests and the local waste management program. Hence, an automatic trash segregation system can also be implemented

3. Delivery Robots: Delivery robots can be perfectly utilized to lend associates a hand for delivery of items, both front and back of the house. Guest requests from the housekeeping desk and other storage areas to their specific rooms can be done by Fully Autonomous Systems, which won't impede on the current tasks done by the floor associate. Alongside this, the collection of dirty linen from outside the doors of guests, and the delivery of them to the laundry department, and the other way around, the delivery of guest linen washed and pressed from the laundry to the guest's room can be done by Fully Autonomous Systems, which will certainly help reduce workload for laundry staff, and they can solely focus on their primary tasks. Moreover, the collection of dirty linen from each and every floor after the morning shift, and its delivery to the laundry department, as well as the delivery of fresh linen and dusters from laundry to the floors, can also be forsaken & assigned to Fully Autonomous Systems, especially with the integration of floor-wise checkouts and number of occupied and departure rooms to further analyze and deliver as many linen as need-be.

   As highlighted in a few examples above, Fully Autonomous Systems can prove to be a highly valuable input in day-to-day housekeeping operations for the hotel, and hence this research specifically collects data regarding such systems and represents the same.

Fully Autonomous Systems in India have already been explored & implemented in industries across India, such as Motor Vehicles implementing Level 2 & Level 3 Autonomy in Cars, Delivery in extremely remote areas in India, especially during Natural Calamities have been done by Fully Autonomous Drones. Many manufacturing plants employ Autonomous machines in their production line as well. Such and many more avenues across the Indian Landscape have already been tried & tested across industries in India.

Objectives of the study:
1. To study the need for Fully Autonomous Systems in the Housekeeping Department.
2. To highlight the potential benefits of Fully Autonomous Systems in the Housekeeping Department.
3. To examine the challenges faced during the adoption of Fully Autonomous Systems in the Housekeeping Department.
4. To create awareness about Fully Autonomous Systems in the Housekeeping Department.

Need & Significance of the study:
The need behind the study is to gain knowledge about the various ways the housekeeping department can be equipped with newer technologies, helping the associates with their work, and the hotel with better efficiency numbers and higher guest satisfaction levels through increasing and maintaining service consistency. Technology usage has increased its significance in various attributes and helps in the ease of the housekeeping operations along with the betterment of guest experience and efficient usage of hotel resources. This research emphasizes the usage of fully autonomous systems and its benefits for the hotels to enhance the performance of the hotel and improve productivity standards of the housekeeping department.

Scope of the study:
This study focuses on the use and implementation of fully autonomous systems in the housekeeping department of hotels. It aims to explore how these advanced technologies impact housekeeping operations, specifically in reducing the workload, anxiety, and stress experienced by housekeeping staff. The research will analyse both the merits and demerits of adopting fully autonomous systems, considering their efficiency, cost-effectiveness, and potential challenges in hotel environments. Additionally, the study will examine how the integration of such systems can enhance the overall guest experience by improving service quality, operational efficiency, and consistency during their stay. This research is limited to the housekeeping department, with an emphasis on practical applications, staff well-being, and guest satisfaction.

Limitations of the study:
This study is limited to 4-star and 5-star hotels, excluding other categories such as budget, boutique, and mid-scale properties, which may have different operations. The research focuses solely on housekeeping professionals, thereby not considering the perspectives of staff from other hotel departments who may also interact with fully autonomous systems. Additionally, the study is restricted to fully autonomous systems that operate independently without human oversight or manual handling, excluding semi-autonomous or partially automated technologies. Furthermore, the data sample is limited to a few selected hotels in India, which may affect the generalizability of the findings to hotels in other countries or regions.

Research Methodology:

This study follows an exploratory research design, focusing on hotels located in Tier 1 cities across India. The primary data was collected through a structured questionnaire specifically designed for housekeeping personnel. This questionnaire was distributed via Google Forms and shared both through in-person visits to various hotels and through online channels to ensure wider reach and participation.

For secondary data, information was gathered from a range of credible sources, including national and international journals, academic articles, and published research papers available in the public domain. A comprehensive literature review was conducted to analyze existing studies, extract relevant insights, and determine the key objectives for this research.

Following data collection, both primary and secondary data were systematically compared and analyzed to identify trends, patterns, benefits, and challenges associated with the implementation of fully autonomous systems in hotel housekeeping operations. This methodology ensured a thorough understanding of the topic, supported by both practical insights from industry professionals and theoretical frameworks from existing literature.

Literature Review:

1. Joaquín López, Diego Pérez, Eduardo Zalama, Jaime Gómez-García-Bermejo (2012) stated in the research paper titled BellBot - A Hotel Assistant System Using Mobile Robots in Intech that there is a growing interest in applying intelligent technologies to assistant robots. These robots should have a number of characteristics such as autonomy, easy reconfiguration, robust perception systems and they should be oriented towards close interaction with humans. In this paper we present an automatic hotel assistant system based on a series of mobile platforms that interact with guests and service personnel to help them in different tasks. These tasks include bringing small items to customers, showing them different points of interest in the hotel, accompanying the guests to their rooms and providing them with general information. Each robot can also autonomously handle some daily scheduled tasks. Apart from user-initiated and scheduled tasks, the robots can also perform tasks based on events triggered by the building's automation system (BAS). The robots and the BAS are connected to a central server via a local area network. The system was developed with the Robotics Integrated Development Environment (RIDE) and was tested intensively in different environments

2. Nick Statt (2016) stated in the blog Hilton and IBM built a Watson-powered concierge robot on The Verge website that Connie, an AI powered concierge robot, named after Conrad Hilton, has been made for Hilton Hotels, with partnership with IBM, is made by a french company Aldebaran. Connie can understand human speech, language, and can extract data through the hotel's website and travel information from IBM Wayblazer. Unfortunately, Connie cannot yet check guests yet, or do anything that will ease the load of current daily check-in checkout tasks, although it answers questions of guests about the restaurants nearby, attractions to visit currently & information about the hotel. Connie, as of 2016, serves as both of an attraction and a travel desk helper, giving information to guests that would otherwise require an employee's extensive amount of time and efforts. The robot, based off another robot Nao, is the start of a range of robotics that will enter the hospitality industry one day

3. Luo Fang (2016) stated in the blog Robots And Guest Experience: Are They Changing The Hotel Industry? on Shiji Group website as to how robots are reshaping the guest experience in hotels. It mentions the increasing use of robots in various hotel functions, such as concierge services, room service, and housekeeping, enhancing operational efficiency and guest satisfaction. Robots are also equipped with sensors and technology that enable them to collect data on guest interactions, preferences, and feedback in real-time, and interact

with guests accordingly, however, this data has to be handled with thorough security measures to ensure guest's privacy. These robots serve as valuable help for hotels to gather data and insights into guest experiences, allowing them to identify trends and areas for improvement. By analyzing the data collected by robots, hotels can gain a deeper understanding of guest preferences and behaviors, enabling personalized services and tailored experiences. Overall, the article emphasizes the Robots have tremendous transformative potential in revolutionizing how guest experience is measured and managed in the hotel industry, through a data-driven approach.

4. Robert Firpo-Cappiello (2017) stated in the blog Friend, Not Foe: Why Hospitality Should Embrace Automation, AI on Hospitality Technology website that it advocates for the hospitality industry's embrace of automation and artificial intelligence (AI) technologies, presenting them as allies rather than threats to traditional hospitality practices. Automation and AI technologies offer numerous advantages, such as streamlining repetitive tasks, reducing labor costs, and increasing productivity. They enable hotels to provide personalized guest experiences as staff workload is reduced, and through data-driven insights and predictive analytics. Moreover, the article discusses how automation and AI can optimize various aspects of hotel operations, including revenue management, marketing, and inventory control. Hotels can make more informed decisions, tailor offerings to individual guest preferences through such data driven analytics. In conclusion, the article encourages hospitality businesses to embrace automation and AI as valuable tools for innovation and improvement and the future, rather than being wary of them

5. Tomomi Kikuchi (2018) stated in the blog At Tokyo's Henn na Hotel, robots run the show on Nikkei Asia website that it explores Tokyo's Henn-na Hotel, where robots play a prominent role in running operations. Henn-na, which translates to "weird" or "strange," is known for its futuristic concept, featuring robotic staff. These robots handle various tasks, such as check-in procedures, making keys, and other assortment of tasks such as providing information to guests in multiple languages. The hotel aims to showcase cutting-edge technology and create a unique experience for visitors. However, despite its innovative approach, the hotel has faced multiple challenges with its robotic staff, including technical glitches and limitations in handling complex guest inquiries. As a result, the hotel has had to rely on human staff to supplement the robots' capabilities, especially for tasks that require multiple layers of complexity and adaptability. Despite the setbacks, Henn-na Hotel remains an intriguing experiment in the hospitality industry's integration of automation and artificial intelligence. This hotel proves as a forefront of the technologies we can expect in the future in all hotels

6. John Bowen and Cristian Morosan (2018) stated in the research paper titled Beware hospitality industry: the robots are coming in Emerald Insight that they predict that by 2030, robots will make up about 25 per cent of the "workforce" in the hospitality industry. The paper also explains the industry challenges the robots will solve, as well as other benefits they provide. One of the findings is that the adoption of robots by the industry will be a disruptive paradigm shift. It will create successful new hospitality companies while putting others out of business. Finally, this paper discusses how to keep the hospitality in hospitality businesses, when machines replace employees

7. Chris Stipes (2019) stated in the blog Robots & Artificial Intelligence, Present Challenges, Opportunities For The Hospitality Industry on University of Houston's website that the integration of robots into the hospitality industry and their potential impact on guest experiences. It discusses how robots are being employed in various roles within hotels. Robots offer several advantages for hotels, such as increased efficiency, reduced labor costs, and the novelty factor that can enhance the overall guest experience. They can perform tasks autonomously, consistently, without much human supervision, freeing up

human staff to focus on more complex guest interactions. The article also informs about examples of robots being used in hospitality settings, such as a robot named "Dash" at a hotel in Cupertino, California, which delivers amenities to guests' rooms. While robots can improve operational efficiency and provide novelty, they have their own face of challenges such as technical limitations and added costs.. A right balance between automation and human interaction has to be ensured for a positive guest experience. Overall, the growing trend of autonomous systems in the hospitality sector is a growing and promising market in the future

8. Stanislav Ivanov (2019) stated in the research paper titled Ultimate transformation: How will automation technologies disrupt the travel, tourism and hospitality industries? in De Gruyter that companies from the travel, tourism and hospitality industry have started adopting robots, artificial intelligence and service automation technologies (RAISA) in their operations. Self-check-in kiosks, robotic pool cleaners, delivery robots, robot concierges, chatbots, etc., are used increasingly by tourism companies and transform the ways they create and deliver services. This paper investigates the impact of RAISA technologies on travel, tourism and hospitality companies – their operations, facilities design, marketing, supply chain management, human resource management, and financial management. The paper emphasizes that in the future companies will divide into two large segments – high-tech tourism companies offering standardized cheap robot-delivered services, and high-touch companies, which rely on human employees.

9. Nikola Naumov (2019) stated in the research paper titled The impact of robots, artificial intelligence, and service automation on service quality and service experience in hospitality in Core UK argues that despite the global acceptance of technologies in service industries in general and hospitality in particular, it remains difficult to find the right balance between digital and human interactions. In the context of service quality, the implementation of robots and service automation is increasingly important for gaining a competitive advantage, but the provision of more personalized guest experiences remain controversial

10. Thomas A. Maier and Ken Edwards (2020) stated in the research paper titled Service System Design and Automation in the Hospitality Sector in Journal of Hospitality that Service system design and customer experience mapping are useful tools capable of improving focus on guest satisfaction and service processes. This integrative-narrative literature review paper (INRP) investigated the technological automations (robots, artificial intelligence and augmented reality) in the hospitality sector for the purpose of gaining the attention of operations managers, hotel chains and academics alike. The INRP investigated how service system design and blueprinting can be utilized to roadmap technology innovations in hotel and restaurant customer experiences. The research is intended to guide hospitality practitioners into new lines of inquiry and facilitate the direction of academic research by determining what needs to be done to narrow the gap among practitioners and academics with respect to how implementation of technological advancements in the hospitality sector can best be approached. A guided framework of key decision points in technological adoption is presented.

11. Georges El Hajal and Bill Rowson (2020) stated in the research paper titled The future of hospitality jobs in Research in Hospitality Management reviews the literature on artificial intelligence (AI)-driven technology and looks at its effects on the future of hospitality jobs, and the skills needed for the future. The purpose of this article is to understand and describe how developments in AI-driven robotics and automation will shape the future of hospitality jobs, the skills in demand, and their impact on the design of education and training. Various input parameters are significant in understanding the future of hospitality jobs. For an optimized understanding, literature has been critically reviewed and investigated from different angles, namely academics, technological advancements, developments in the

industry, and governments and policymakers. The literature reveals that AI-driven technology is developing at a very high speed and shows its extensive application in tourism and hospitality management and other related industries. Many of today's jobs will be lost to AI, automation and robotics, and new jobs with new skill-set requirements will emerge. Education establishments will have to adopt a new futureproof educational system or risk becoming obsolete. This review article will be beneficial for industry and education. The article reveals the detailed literature review on jobs that are at high risk of disappearing and offers an insight into what future jobs might be and what skills and competences will be required

12. Chris Connor (2021) stated in the blog Is Robotics Taking Over Hospitality? Yes & No on PhocusWire website that explores the pros and cons for robotics in the hospitality sector
Pros -

- Offering a contactless experience, especially after COVID
- Boost efficiency & productivity, as robots and AI can work 24x7, without any vacations or breaks, productivity and efficiency levels are through the roof
- Assistance with cleaning tasks is a no-brainer, since sanitization and cleaning are pretty straightforward tasks, those can be easily taken over by robots
- With robotics handling much of the work, employees can focus on ensuring as to how to personalize the guests stay and make it memorable

Cons -

- Extremely high implementation aka upfront costs make it a non-convincing deal for hotels
- Regular maintenance and software updates are required for the robots for smooth functioning
- Glitches and hacks are a dangerous aspect since the technology is pretty new, and hence security has to be taken seriously
- According to the other, based on the current parameters, a hybrid model wherein robots help the humans should be implemented

13. Viktor Michel-Häggström (2021) stated in the blog How to Improve your Hotel through Automation: New Things You Need to Know on Metasphere website essentially analyzes the automation in 4 levels,
Basic automation for the simple tasks
Process automation for the automation of workflow & processes
Integration automation mimicking human tasks
Artificial intelligence (AI) who themselves learn & improvise based on previous data & experiences
Always striving for a personalized guest experience & streamlining the operations while increasing efficiency has been a core focus of the hospitality industry, & hence hoteliers are now relying on automation to help them in that aspect. Hotel automation is being used in both front end & back end of the hotel industry & it has currently been gaining popularity even though technology has been around for a long time because it was always believed that it hampers the guest's experience without associates, but the COVID-19 pandemic has made the industry realize it's use case & the helping hand provided by the automation. It has its fair share of advantages & disadvantages, with advantages such as an efficiency increase in the organization, improving employee satisfaction by eliminating boring & mundane tasks, helping save guests time & enhance their experience through predictability, while the disadvantages range from negatively impacting the guest's experience, or may create rifts as jobs are being impacted, & then the heavy cost factor of both establishing & implementing the system, as well as the resource intensive task both for employee & guests to learn all these new stuff.

14. Sungwoo Choi, Ph.D. (2021) stated in the blog The Rise of Service Robots in the Hospitality Industry: Some Actionable Insights on Boston Hospitality website explores the growing presence of service robots in the hospitality sector. Highlighting the COVID-19 pandemic's acceleration of automation trends, it emphasizes how service robots are becoming integral in various hospitality functions, from customer service to cleaning and room service. Robots minimize human contact and enhance hygiene protocols , exactly what the guests' expectations are these days for safety . Concierge services, food delivery, and housekeeping tasks and more are a few ways robots can help leading hotel chains and businesses. Additionally, challenges and opportunities associated with robots, such as initial costs, technological limitations, and the need for staff training. Despite these hurdles, the author emphasizes the long-term benefits, including cost savings, improved guest experiences, and enhanced operational efficiency. Robots can position hospitality businesses for sustained growth and competitiveness in an increasingly digital landscape.

15. Francesc Fusté-Forné and Tazim Jamal (2021) stated in the research paper titled Co-Creating New Directions for Service Robots in Hospitality and Tourism in MDPI that research on the relationship between automation services and tourism has been rapidly growing in recent years and has led to a new service landscape where the role of robots is gaining both practical and research attention. This paper builds on previous reviews and undertakes a comprehensive analysis of the research literature to discuss opportunities and challenges presented by the use of service robots in hospitality and tourism. Management and ethical issues are identified and it is noted that practical and ethical issues (roboethics) continue to lack attention. Going forward, new directions are urgently needed to inform future research and practice. Legal and ethical issues must be proactively addressed, and new research paradigms developed to explore the posthumanist and transhumanist transitions that await. In addition, closer attention to the potential of "co-creation" for addressing innovations in enhanced service experiences in hospitality and tourism is merited. Among others, responsibility, inclusiveness and collaborative human-robot design and implementation emerge as important principles to guide future research and practice in this area.

16. Boyu Lin & Woojin Lee (2021) stated in the research paper titled Trust Building for Autonomous Service Robots in Hotels in ScholarWorks that Hotels are increasingly adopting autonomous service robots and this trend has been accelerated by the event of the COVID-19 pandemic. Thus, customers will have more opportunities to interact with these innovations. Therefore, there is a need to identify the factors that affect the guests' initial trust in these service robots and their willingness to adopt these applications in hotels even after this pandemic. The proposed mixed method will be applied to investigate the expected following results,

    1) four exogenous variables of the UTAUT (performance expectancy, effort expectancy, social influence, and facility condition) have distinctive effects on initial trust

    2) the three forces of ITM (institutional, personal and environmental factors) affect the initial trust, which contributes to the intention to adopt autonomous service robots in hotels

    3) familiarity with the autonomous service robots moderates the relationship between the four constructs in UTAUT and initial trust.

17. This paper highlights the value of the initial trust and the moderator of familiarity, which are expected to have a significant impact on the intention to adopt autonomous service robots in hotels in the post-pandemic age. The theoretical and practical implications will be discussed

18. Małgorzata Sztorc (2021) stated in the research paper titled Autonomous Enterprise as a Model of Hotel Operation in the Aftermath of the COVID-19 Pandemic in MDPI explores

how the COVID-19 pandemic has driven hotels to adopt automation and innovative technologies, reshaping their operations into autonomous entities. Through a survey of 462 three-, four-, and five-star hotel representatives from June to September 2021, the study identifies tools and technologies facilitating digital transformation and crisis response. Findings indicate a shift towards autonomous hotel models, emphasizing swift decision-making and crisis management. Statistical analysis reveals the significance of process optimization and digital ecosystems in this transformation. The research underscores the urgency for hotels to integrate technological solutions, adapting to pandemic challenges and enhancing operational resilience in the hospitality sector.

19. Tobias Roelen-Blasberg (2022) stated in the blog Take Hotel Management to the Next Level with AI: Essential Tools Every Hotelier Needs on Mara Solutions website discusses how artificial intelligence (AI) is revolutionizing hotel management and how AI can be utilized by hoteliers. It emphasizes the potential of AI in various aspects of hotel operations, including guest experience, revenue management, and operational efficiency. One crucial AI tool highlighted is chatbots, which can enhance guest interactions by providing instant responses to inquiries, booking assistance, and personalized recommendations. Such chatbots greatly reduce staff workload. Another key AI use is revenue management systems, which utilize data analytics and machine learning algorithms to optimize pricing strategies, forecast demand, and maximize revenue. By analyzing historical data and market trends, these systems enable hoteliers to make data-driven decisions that optimize profitability. The AI can also help analyze data and subsequently ensure highly effective marketing strategies. Overall, AI greatly helps hoteliers in various aspects of the business

20. Lionel Saul (2022) stated in the blog Service Robots and AI: What impact on the future of Hospitality? on EHL Insights website that it emphasizes that while robots are not intended to replace human interaction entirely, they can certainly enhance efficiency and improve certain aspects of service delivery. Robots offer various functionalities, including delivering amenities, providing information, and even offering entertainment to guests. Service robots can reduce labor costs, increase operational efficiency for hoteliers, especially for tasks such as housekeeping and room service. However, challenges such as high initial investment costs, maintenance requirements, and concerns about job displacement from the employee unions need to be addressed for widespread adoption of such autonomous technologies. A balance between human touch and technological innovation has to be maintained in hospitality, to ease the transition. Human interaction still remains crucial for personalized and emotionally resonant guest experiences. Overall, the author advocates for a strategic approach to integrating service robots into hospitality operations.

21. Kim Campbell (2022) stated in the blog Hotel Automation: Trends, Tools, & Tips to Know on Cvent website that it essentially talks about the benefits of hotel accommodation to the hotel implementing the technology, which all processes can hotels automate, how it'll impact the guest interaction, & how the hotel can get started for the same. The benefits of implementation of automation include the reduction of labor costs, & subsequently supporting short-staffed teams, all while helping streamline & equalize the services offered, ensuring the quality is kept at the hotel's standards, as well as helping out the hotel's sales management, all in the meanwhile improving the guest experience with new technologies, which proves to be an enticing factor for tech-savvy travelers, as well as being able to analyze data more efficiently, helping in forecasts of demand & utilization rates & occupancy percentages. Newer technology also helps in enhancing inter-departmental & intra-departmental communications, as well as cutting hotel's expenses in innovative ways. Systems that can be automated in hotels are system integration services such as revenue management, pricing & rate utilization optimizations, as well as helping out the sales &

marketing department in their day-to-day activities, all while automating mundane tasks such as RFP management & check-in services. From the guests perspective, digital room keys on their phones, self check-in kiosks, information kiosks for further efficiency of information, digital menu boards as well as automated messaging software such as DND preferences & spa packages. Hotel's to get started with the hotel automation process have to ensure that all the procedures aren't revolutionized too quickly, since multiple factors such as money & staff trainings have to be implemented as well, & then checking in & analyzing on which all operations are the most inefficient in the hotel, & subsequently automating the same, after which the right software & the right level of automation has to be implemented depending on the hotel, & while doing the same, testing the accuracy & effectiveness of the systems used.

22. Gerry MacPherson (2022) stated in the blog A Quick Guide To Hotel Automation For Independent Properties on Cloudbeds website that it primarily concerns the digital transformation of all companies, especially during the pandemic, & how hotels can implement the same. The benefits of such automation is increasing efficiency & productivity, all while improving the speed & consistency of guest service, contact-free service options, with the help of saving in labor & operating costs, helping the organization increase revenue simultaneously, & both the factors helping increase profitability, reducing errors from manual work, & helping manage data better & track performance accordingly. 2023 has seen a heavy rise in automation in other sectors, & the hospitality industry can certainly embrace automation technology, especially in the back office departments which will ensure that the human touch is not reduced. Tasks automated for hotels are primarily the check-in checkout processes, online reservations, as well as messaging services between the hotel & the guest & the complaint services. Hotel automation services no doubt will be highly expensive to setup & run, but the long term benefits are to be reaped for years to come. The top 4 hotel automations on priority are the hotel operations automation, such as PMS systems & management software, the guest experience automation, such as communication & check-in, the guest room automation, and marketing automation

23. Menilik Henry Dryer (2022) stated in the blog Why Hotel Automation is the Next Big Thing in Hospitality on Preno website talks about how technology has already been implemented in hotel industries & how automating such technologies seems like the most logical step now that the tech is enabling, more than ever. In his words, "Automation streamlines tasks & enhances efficiency along with reliability & overall quality. It essentially converts inefficient, disconnected & independent processes into simplified, integrated, & automated workflow". The benefits for automation as discussed are enabling the associates to focus on the customer experience & the guest preferences & a personalized touch, as well as helping ease communication between departments & within a department, increasing the hotel's visibility with third party agencies, helping lower operations costs.The article also talks about how automation has to be successfully implemented to ensure that the human touch of personalization which the guests love is not lost during the transition & instead only the mundane, repetitive & cumbersome tasks are handled by the automated systems while the employees focus on the betterment of the guest experience & taking over from the systems in case of any problem or complications arise.

24. Kate Kaye (2022) stated in the blog What it's like to stay & work in an automated hotel on Protocol website that essentially talks about the Sextant hotel in New Orleans & how they have implemented various technologies in their hotel, such as, A virtual concierge computer greets guests on a computer monitor, the person actually being thousands of miles away, & the guests can pay $5 for a shot of bourbon dispensed by a robot on the bar if they please. The article also talks about how automation does add a sense of novelty & convenience, it also is highly prone to technical glitches & unique labor dynamics. The

virtual concierge is actually a person in the Philippines & is only visible to the guest on a screen on the front desk, & all concerns are addressed accordingly. Such one of ten full time concierge associates are there on call 24x7 to help guests if required, with self-check in as the primary mode of check-in, & it allows sextant to pay only 10 concierge staff instead of 30, hence reduction of operating costs, & with offshore labor helping bring in a sense of diversity to the hotel & area, & even though the human is remotely available, they are still always important & required for complex guest needs & overtaking when the systems fail. All the smart lock details for the room are received by the guest on their phones, & clear instructions help avoid confusion with regards to utilizing the new software. The validity of documents is also taken care with high quality cameras scanning documents & a person's face & verifying accordingly, as well as the use of facial recognition software being helpful to run ID's through the government's verification software. Technologies also replace what usually would've been a call to the front office for medicine or extra supplies, to an app wherein the robot delivers it in front of your door, & screens installed in every room help the guest arrange for room cleaning & where all the items in a room are kept, as well as ensuring they are briefed regarding all facilities provided. Coupled with various other sensors for noise & thermals, guests can be informed accordingly if they are being too noisy & all interactions with the guest occur through the screen in their room. Although automation is at the core of this hotel, not all labor can be eliminated, & cleaning tasks especially, although also assisted by automation with the help of robots, still need labor, albeit as minimal as possible, & the maintenance of any equipments required need humans.The hotel industry may have a hard time juggling between just how much automation has to be implemented to balance the novelty & convenience of automation, all while ensuring the personalized human touch isn't lost.

25. Charlotte Hu (2022) stated in the blog Robot-run hotels are here, but guests have mixed reviews on Popsci website talks about how hotels are looking to automate their services such as check-in check-out, room service, vacuuming carpets, digital room keys & luggage transportation, & how they are turning towards robots to help them with the same. The primary reason behind the same being the ultimate goal of saving costs, & robots are an amazing solution to the problem. A japanese hotel by the name of "Henn Na", tried to do the same but unfortunately ran into way too many problems & had to employ more staff to upkeep with the same, so hotels moving forward with robots have to ensure they work out any kinks in the situation, & humans trained to take over if any problems arise, as well as humans to repair the robots if any issue is faced. Another issue the hotels & especially guests may have are the privacy concerns regarding the data collected by AI & robotics platforms, especially since they have microphones & cameras in them. In the end, robotics can definitely handle repetitive & predictable tasks such as room delivery, luggage carrying, vacuuming & such tasks are completed with ease. Manufacturers should definitely make robots specifically for a hotel setting, & provide software solutions & hardware support & help 24x7 to employees for an easier experience for all.

26. Eva Lacalle (2022) stated in the blog What Are The Benefits Of Hotel Automation For Small Properties on Mews website that essentially discusses hotel automation, especially for small properties & how it can be implemented for them. The benefits include an improve in employee satisfaction as the mundane tasks are handled & the employees can focus on helping the guest experience, Helping operations run smoothly since automation helps provide more efficient, accurate & faster service & overall operations were better, as well as Improving the check-in process, as it's one of the most time consuming process, & that too the first process as the guest arrives in the hotel. Data & market intelligence isn't really a top priority for a small hotel due to its resource heavy nature, & hence data analyzation & data driven decisions can be easily concluded through data automation. A small property

has total control in the owner's, & automation helps the owner handle so many aspects of running the hotel, since the automation does the heavy & mundane tasks for the owner, with them only having to make executive decisions accordingly in order to actually run the business & drive it in the right direction.

27. Angelo Directo (2022) stated in the blog Robotic Process Automation Will Shape the Future of Hotel Operations on Hospitality Net website how the hospitality industry is turning to Robotic Process Automation (RPA) to address challenges such as rising labor costs and staffing shortages that were aggravated by the COVID-19 pandemic. RPA essentially streamlines tasks by utilizing robots to handle repetitive & mundane tasks, freeing up human employees for more personalized tasks and the human touch for guest's stay. Despite initial hesitancy, RPA is gaining traction in both guest-facing and back-of-house operations, such as marketing automation, revenue management and operating efficiencies. RPA reduces manual efforts and enhances efficiency, such as automating sales Request Proposals, managing rates, and revenue reporting. Coordination between hoteliers and technology providers is crucial to ensure successful integration of automation solutions. Trust and confidence in the technology is also crucial in the start to help get the new technology off the ground.

28. Alfredo Pastor Tella (2022) in the blog Humans & Robots Are Better Together for Hotel Guest Experience : Advantages & Disadvantages of Installing Robotics in Hotels on AGV Network website talks about how in the age of robotics & artificial intelligence, the hotel industry can implement robots in their day to day life & what their pros & cons will be. The article talks about how robotics can be an intriguing & novel & helpful concept in the hospitality sector, although the human touch may feel lacking to some. The Advantages discussed in the article are a few such as the fact that robots help make checkin easier, as they operate faster than humans & hence reduce wait time, alongside the fact that humanoid robots may even be better than just screens, & human errors are none, although a human should be present to oversee in case anything goes wrong. An important hygienic factor, especially after COVID-19, is the spread of germs, & fortunately robots are amazing at that too since they don't transmit diseases. Another human factor is shift timings & tiredness, through which robotics work better since they can work 24x7 without rest, food, water, smoke breaks & without complaints. Robots also free up the employees working from boring mundane tasks & instead the focus of employees can be concentrated on better factors such as personalizing high value services such as complaints & personalizations, as well as important paperwork required. Robots also help bring variable costs down, such as 1 robot can take luggage which takes 3 employees to do the same, & many more examples. Robots also help with consistency amongst services & don't get sick or tired or offended, resulting in reduction of quality. Another amazing factor of robotics is the fact that tech savvy guests will absolutely adore the technology & would choose your property over others due to the tech factor primarily. Robots also make fewer mistakes, & once programmed, will never make it again. Even though so many advantages can be seen & are pointed out above, it's not all hunky-dory, & many disadvantages arise through the implementation of robotics, such as, Robots may not really be suitable for the hospitality sector, since people sometimes not like being served by robots, & the sector highly values a warm & welcoming feeling & a human touch towards all the services. Some guests may also hate robots because of the lifeless & monotonous service that they provide, & want a human touch to the service they're being provided. Robots also cannot really personalize services for guests on the fly based on instant requests & quick replies to guest's special needs, & humans need to step in at this point. Another highly unfortunate & hindering factor is the very high monetary investment factor, only really possible by big hotel chains. Robotics also heavily depend on technology which is highly prone to breaking down &

malfunctions, during which humans have to step in.. Another huge investment point is the skilled staff required to run the robotics on the hardware level, with maintenance & repairs required, software level with help for the same, & alongside employees who can step in if the robots are not able to handle the current situation.

29. Olga Vasylieva (2023) in the blog Hotel Automation: Benefits & Tools to Improve Operations on Oaky website discusses what automation is, examples of it in the industry, benefits of implementation of the same in hotels & which tasks are worth automating. Benefits of implementing automation range all the way from increasing efficiency for routine operations in order to ensure all team efforts are directed in a common direction, as well as reducing the amount of human error that is an unfortunate part of the process. Automation also helps efficiently utilize the resources, in regards to helping use fewer resources overall, while ensuring that guest interactions are elevated to the next level. A reduction in carbon footprint is also beneficial both for the hotel's image & the environment. Operational tasks such as managing the inventory & managing the task assignments for associates, with the check-in process being a primary goal for automation, as well as implementing automation in guest rooms to increase guest experience, alongside helping in communication with guests for their further satisfaction, all while helping us upsell more effectively, & having an assurance in the topmost level of service quality offered, all while managing the entire revenue system to ensure utmost profits, is where the focus of implementation of automation shall be concentrated. The selection of the best automation for the hotel to suit its needs include the analysation & consideration of the comfortability of the target guests, analyzing which tasks require automation the most, since they are struggling right now, understanding the underlying costs & the subsequent Return-On-Investment of the implementation of hardware, as well as checking user reviews to ensure the value from the specific technology is well considered.

30. Jeff Linnel (2023) stated in the blog Solving The Need For Robotics In Hospitality Facilities on Forbes website how the increasing demand for robotics in hospitality facilities and strategies to implement robotics solutions in the industry, emphasizing the significant benefits that robotics can offer in terms of enhancing operational efficiency, improving guest experience, and addressing labor shortages. Several key areas where robotics can help in the hospitality industry are areas such as housekeeping, room service, and customer service. Automating repetitive tasks and streamlining work order are the best ways robots can help reduce costs and better allocate resources. Selecting the right robotics solutions is based on the specific needs and requirements of each hotel. Thorough research and evaluation has to be done to identify robotics technologies that will help the hotel in the best way possible. Staff also has to be trained to work alongside robotics and adapt to changes in their roles and responsibilities. Robotics can certainly take over the mundane and repetitive tasks during the day, human interaction and personalized experiences remain essential for a great stay.

31. Parmy Olsen (2023) stated in the blog Your First Robot Butler Will Need Human Eyes on Bloomberg website that while companies like Tesla and Figure are developing walking robots with arms for tasks like stacking warehouse goods, London startup Prosper Robotics is taking a different approach with their robot called Alfie. Alfie is controlled by humans in the Philippines through VR headsets, for hotels, folding towels and making beds. These operators use their movements and VR controllers to steer Alfie and perform tasks like cleaning and making beds. Privacy concerns are a thing, but the founder Shariq Hashme assures users that operators won't be able to see faces or read text and customers can stop the robot anytime they choose. This human-assisted approach is necessary to gather training data, for eventual true robot autonomy, estimating we'd need 10,000-100,000 robots with human operators before they can function independently. Ultimately, the company sees a

future where robots are overseen by humans, which might be more comforting to the public than completely autonomous machines. Prosper robotics eventually means to start selling such robots to hotels to help them accomplish tasks as quickly and without much intervention.
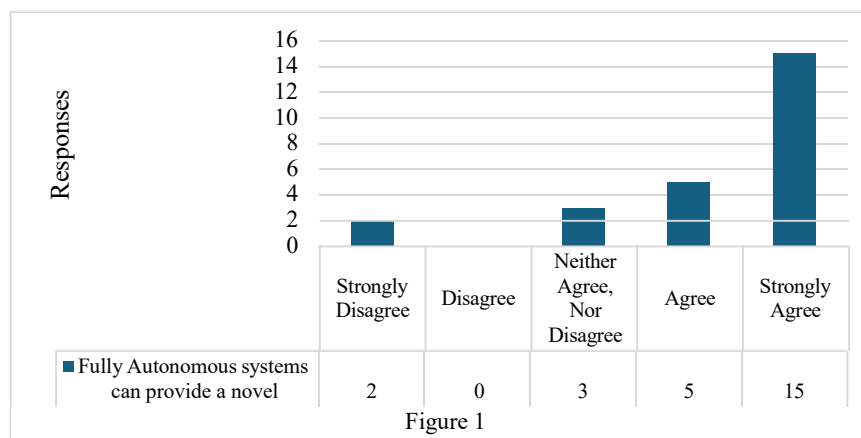
32. Pavel Makarevich (2023) in the blog Enhancing Guest Experience: The Role of Robots in Hotels on Proven Robotics website talks about the role of robots in enhancing the guest experience within the hotel industry. It highlights how robots can be utilized across various hotel functions to improve efficiency, service quality, and guest satisfaction. Robots can be deployed in tasks such as check-in and check-out processes, room service delivery, concierge services, and housekeeping. Automating these tasks, hotels can aim to increase efficiency, and improve overall service to every guest. The article also emphasizes the potential benefits of including robots into hotel operations, increased productivity, cost savings on both labor and resources, and the ability to offer novel and memorable guest experiences. Furthermore, it discusses how robots can complement human staff rather than replace them, allowing employees to focus on more personalized guest experience. Despite the advantages, the article also includes challenges associated with robot adoption, everything from the upfront costs required to the extensive resource allocation towards the technical aspects of them.

33. Robyn Jesson (2023) stated in the blog Hotel Automation: Tools & Tips for Better Operations Performance on Operto website that the benefits of using a hotel automation system, ranging from an independent guest experience, to a higher level of guest engagement with their stay, to a more genuine interactions with guests, as well as more operational oversight with the automatic equipment, & the reduction of staffing costs as well. The tasks worth automating in the current day are, Pre-stay guest engagement, with a messaging solution before the stay period, to start building a relationship as well as a way to upsell, Checkin-Checkout process, with automatically syncing with PMS for keys & rooms & identity verification & links, Employee Scheduling & Reporting, with software automatically adjusting & making duty rotas for the employees, understanding & analyzing their personal needs for holidays & timings accordingly, as well as payroll automation, to automatically understand & implement overtimes & monthly pays, as well as helping in energy saving with automatic turning on & off of equipments & the increased efficiency with the help of analyzation of the condition of equipments.

34. Daniel Bermany (2023) in the blog Revolutionizing The Hospitality Industry With Artificial Intelligence on Forbes website, informs us about the impact of artificial intelligence (AI) in the hospitality industry, its potential to revolutionize various aspects of guest experience and operational efficiency. AI technologies can enable hotels to personalize guest interactions & streamline operations. AI can have a profound impact in the hospitality sector, such as guest communication, demand forecasting, personalized recommendations, and pricing strategies. AI-powered chatbots and virtual assistants enable real-time communication with guests, addressing their inquiries and enhancing customer satisfaction. AI algorithms can analyze vast amounts of data to predict guest preferences, behaviors, and demand patterns, enabling hotels to further tailor their offerings and marketing strategies accordingly, helping hotels optimize inventory management, pricing, and resource allocation, ultimately improving revenue and cost efficiency. Ultimately, AI has to be used ethically, ensuring guest data and privacy and security is prioritized above everything.

35. Theodore Koumelis (2024) in the blog COVID-19's influence on hospitality: Embracing robots for enhanced safety on TravelDailyNews website examines the impact of COVID-19 on the hospitality industry and how the increasing adoption of robots can enhance safety measures. With the pandemic prompting a focus on health and safety protocols, hotels are

turning to robots to minimize human contact. Robots are now utilized in various capacities, including cleaning and disinfection, food and beverage service, and guest interactions. These robots offer several benefits, such as increased efficiency, consistency in sanitization procedures, and the ability to operate 24/7 without the need for breaks or constant supervision. By automating tasks traditionally performed by human staff, hotels can prioritize guest safety as humans can focus on other complex tasks and guest satisfaction. The article also gives various examples of hotels and resorts worldwide wherein they've implemented robotic solutions, such as UV disinfection robots, delivery robots for room service, and humanoid robots for guest services (which are more personal in nature)

36. Swati Aggarwal, Anshul Mittal (2024) stated in the research paper titled Futuristic hospitality conceptualized: DASH - Decentralized Autonomous and Smart Hotel that ubiquitous hospitality has stimulated a rise in expeditions to inspiring getaways and extraordinary destinations. It is imperative for hotels to create a distinct and immersive experience leveraging disruptive technologies like Artificial Intelligence, Machine Learning, Internet of Things, and Blockchain, while ensuring economic affordability for patrons. This study introduces an autonomous and agile smart hotel system, DASH-Decentralized Autonomous and Smart Hotel system, operating on a pay-per-use model, meticulously tracking the usage of amenities and utilities for patrons. The proposed system is an amalgamation of Internet of Things, Robots, Artificial Intelligence, and Blockchain, each enhancing trust, transparency, and underlying operations while reducing workforce and operational costs. This work distinguishes itself by focusing on the complete automation of hotels rather than merely complementing current activities with these technologies.

Data Analysis:

As per data collected from 25 hotels across India, 91% respondents were familiar with the concept of fully autonomous systems used in housekeeping department. They were highly eager towards the implementation of such systems in India, with emphasis on it will help reduce workload, especially on peak business days, and will help with consistency in service, smooth out operations & increase efficiency. However, some have concerns about initial costs & compatibility with current hotel dynamics. They also mentioned that it would lead to smooth service for the guests, and staffing can be done in the most optimum manner. Also, from the hotel's perspective, associates will be able to complete their shift on time, resulting in an increase in employee morale and job satisfaction and general work-life balance. A respondent also highlighted that such a system will be a great fit for guest requests, as they'll be done Fully Autonomous System and the current housekeeping staff won't have to stop their work to

	Strongly Disagree	Disagree	Neither Agree, Nor Disagree	Agree	Strongly Agree
Fully Autonomous systems can provide a novel	2	0	3	5	15

Figure 1

accommodate the request. Another respondent also mentioned that in the current market it might not be feasible to bring technologies to India but definitely would help in the future.

The data (Figure 1) reflects respondents' opinions on whether fully autonomous systems provide a novel experience to guests. A majority of respondents (75%) have a positive outlook, with 15 strongly agreeing and 5 agreeing, indicating that most perceive autonomous systems as enhancing guest experiences. A small portion (15%) remains neutral, with 3 respondents neither agreeing nor disagreeing, suggesting some uncertainty or lack of strong opinion on the matter. Only 2 respondents (10%) strongly disagree, while no one disagrees, indicating minimal opposition to the idea. Overall, the results suggest that fully autonomous systems are generally viewed favourably, with most respondents recognizing their novelty and potential impact on guest experiences.

Benefits of using FAS

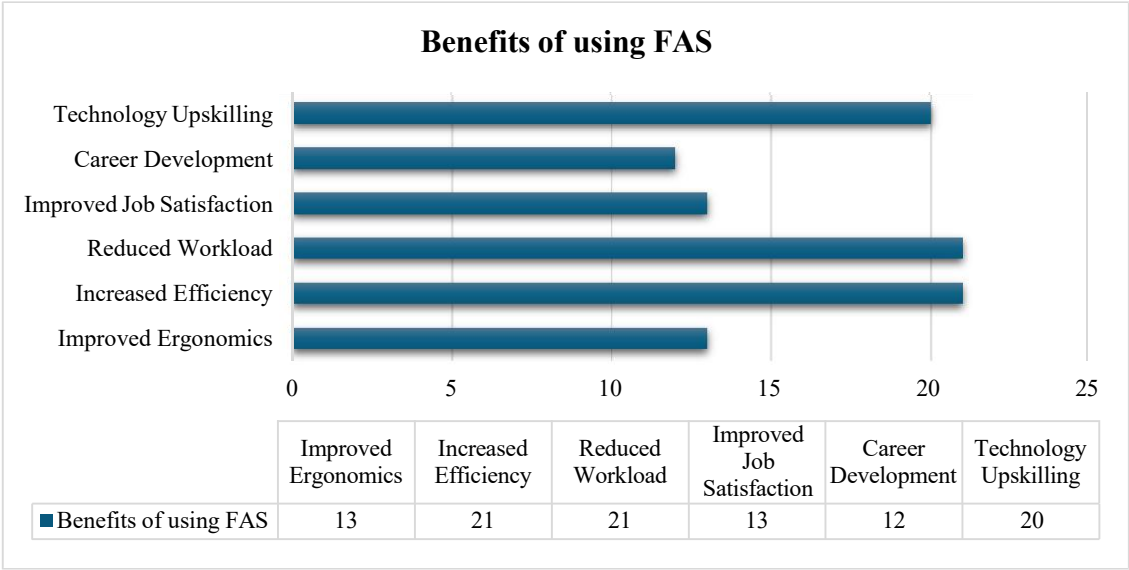|	Improved Ergonomics	Increased Efficiency	Reduced Workload	Improved Job Satisfaction	Career Development	Technology Upskilling
■ Benefits of using FAS	13	21	21	13	12	20

Figure 2

The responses indicate the perceived benefits (Figure 2) of housekeeping staff working alongside fully autonomous systems. Increased Efficiency (21) and Reduced Workload (21) received the highest responses, suggesting that staff see automation as a means to streamline tasks and lessen physical strain. Technology Upskilling (20) is another significant benefit, showing that employees recognize the potential for learning and adapting to new technological advancements. Improved Ergonomics (13) and Improved Job Satisfaction (13) are moderately acknowledged, indicating that automation might reduce physical strain and contribute to a more satisfying work environment. Career Development (12) received the least responses, implying that
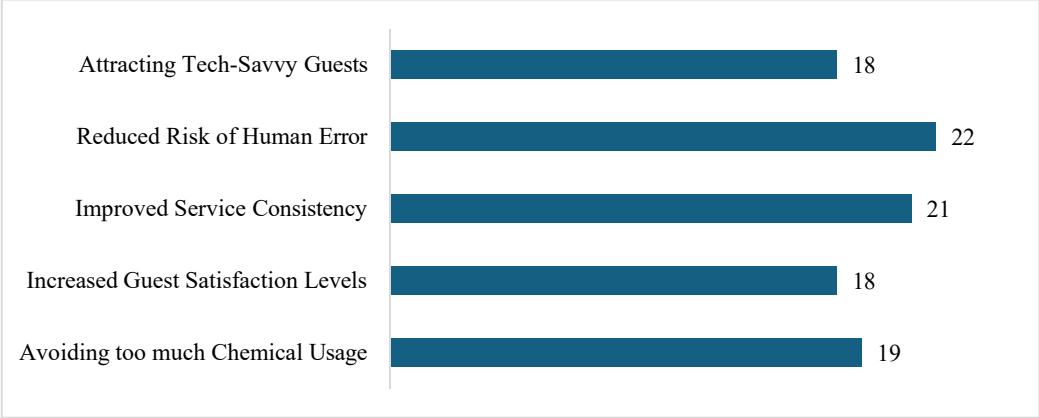

Figure 3

while automation is seen as beneficial, its role in career growth is perceived as relatively lower.

The responses highlight the key benefits hotels perceive (Figure 3) in adopting fully autonomous systems. Reduced Risk of Human Error (22) received the highest response, indicating that automation is seen as a way to enhance operational precision and minimize mistakes in housekeeping and guest services. Improved Service Consistency (21) is also highly rated, suggesting that hotels value automation for maintaining uniform service quality. Avoiding Too Much Chemical Usage (19) is a notable benefit, reflecting environmental concerns and cost savings related to reduced chemical dependency in housekeeping. Increased Guest Satisfaction Levels (18) and Attracting Tech-Savvy Guests (18) are equally rated, indicating that automation is expected to enhance the guest experience and appeal to a more technology-oriented clientele.

Both datasets highlight the perceived advantages of Fully Autonomous Systems (FAS) from two perspectives: housekeeping staff and hotel management. A comparative analysis reveals several key correlations:

1. **Efficiency, Workload Reduction & Service Consistency**
   - Housekeeping Staff: *Increased Efficiency (21) & Reduced Workload (21)*
   - Hotel Perspective: *Improved Service Consistency (21) & Reduced Risk of Human Error (22)*

Housekeeping staff see automation as a way to improve efficiency and reduce workload, while hotels recognize these benefits as enhancing service consistency and minimizing human errors. This suggests that automation streamlines hotel operations while making staff roles more manageable.

2. **Technology Upskilling & Attracting Tech-Savvy Guests**
   - Housekeeping Staff: *Technology Upskilling (20)*
   - Hotel Perspective: *Attracting Tech-Savvy Guests (18)*

The integration of autonomous systems leads to technology upskilling among housekeeping staff, aligning with the hotel's goal of attracting tech-savvy guests. This implies that as staff become more adept at using technology, hotels can market this as an advanced service offering.

3. **Ergonomics, Job Satisfaction & Guest Satisfaction**
   - Housekeeping Staff: *Improved Ergonomics (13) & Improved Job Satisfaction (13)*
   - Hotel Perspective: *Increased Guest Satisfaction (18)*

Automation reduces physical strain and improves job satisfaction for housekeeping staff, which may lead to better service delivery. This contributes to higher guest satisfaction, showing a direct link between employee well-being and customer experience.

4. **Environmental Sustainability & Work Efficiency**
   - Housekeeping Staff: *Reduced Workload (21)*
   - Hotel Perspective: *Avoiding Too Much Chemical Usage (19)*

Autonomous systems help hotels control chemical usage while reducing the burden on housekeeping staff. This suggests a sustainability aspect where automation not only enhances efficiency but also promotes eco-friendly practices.

5. **Career Development & Risk Reduction**
   - Housekeeping Staff: *Career Development (12)*
   - Hotel Perspective: *Reduced Risk of Human Error (22)*

While automation is recognized for reducing errors, it is less associated with career growth by housekeeping staff. This gap suggests that hotels may need to implement structured career development plans alongside automation to ensure staff see long-term benefits in their roles.

The responses also highlight the key challenges (Figure 4) hotels perceive in adopting Fully Autonomous Systems (FAS):

1. *High Capital Costs (21) & Machine Errors/Malfunctions (21) – Major Concerns*
   Both factors received the highest responses, indicating that the initial investment and reliability of automation are the biggest deterrents for hotels. While automation promises efficiency, the high upfront cost and potential malfunctions create uncertainty about return on investment (ROI). Hotels may hesitate to adopt FAS unless they see clear long-term savings and reliability improvements.
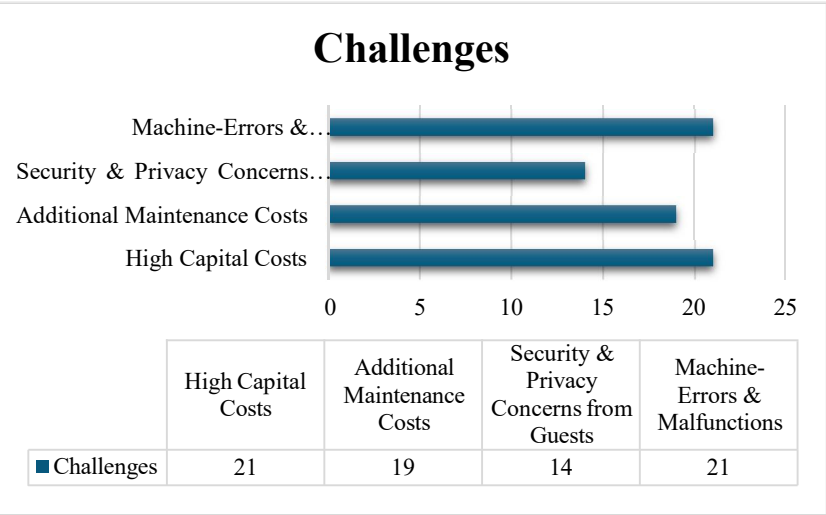

Challenges

	High Capital Costs	Additional Maintenance Costs	Security & Privacy Concerns from Guests	Machine-Errors & Malfunctions
■ Challenges	21	19	14	21

Figure 4

2. *Additional Maintenance Costs (19) – A Significant Challenge*
   Hotels are concerned about ongoing expenses related to software updates, repairs, and technical support. While automation may reduce labour costs, the need for continuous maintenance can offset some of these savings. This suggests that hotels must evaluate the total cost of ownership rather than just the initial investment.

3. *Security & Privacy Concerns from Guests (14) – A Moderate Issue*
   Compared to other concerns, privacy and security risks received fewer responses, but they remain relevant. Guests may feel uneasy about AI-driven systems handling personal data, especially in luxury or high-end hotels where privacy is a priority. Hotels adopting FAS must implement strong cybersecurity measures and transparent data policies to maintain guest trust.

The sample indicates a general agreement that Fully Autonomous Systems (FAS) have the potential to lead to long-term cost savings, though opinions vary based on initial investment, maintenance, and hotel category. Many respondents acknowledge that manpower costs are among the highest expenses in hotels, and automation can help reduce fixed labour costs and human errors, making operations more efficient. However, a significant concern is the high initial capital investment and ongoing maintenance costs, which some believe could delay ROI. Several responses suggest that FAS may be more viable for large or branded hotels, where frequent usage justifies the cost, while standalone properties may struggle with affordability. Others highlight that cost savings depend on proper utilization and operational consistency, as underused systems may not be cost-effective. A few respondents express uncertainty about the financial impact, citing a lack of knowledge about implementation costs. Overall, while most agree that automation can be economically beneficial in the long run, its adoption depends on financial feasibility, scale of operations, and strategic implementation.

The responses highlight specific housekeeping tasks (Figure 5) that are perceived as most suitable for automation through Fully Autonomous Systems (FAS):

1. **High Suitability for Automation**

    Room Vacuuming & Mopping (20), Exterior Window Cleaning (20), and Lawn Maintenance (20) received the highest responses, indicating that physically demanding and repetitive cleaning tasks are the best candidates for automation. These tasks require consistency and efficiency, which autonomous systems can achieve without fatigue. Robots designed for vacuuming, window cleaning, and lawn maintenance can enhance productivity while reducing labour-intensive efforts.
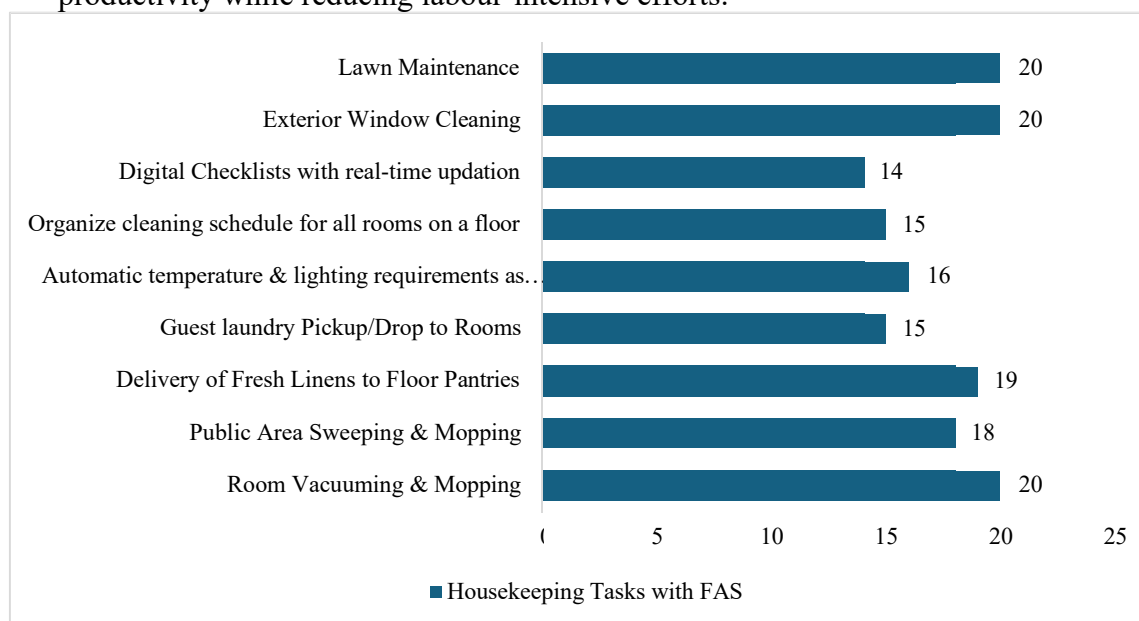

Figure 5

2. **Moderate Suitability for Automation**

    Delivery of Fresh Linens to Floor Pantries (19) and Public Area Sweeping & Mopping (18) suggest that automated logistics and routine cleaning of shared spaces are also highly valued. Robotic linen delivery carts and AI-driven public area cleaning machines could streamline operations and free up housekeeping staff for guest-focused tasks.

3. **Guest Service & Energy Efficiency Automation**

    Automatic Temperature & Lighting Adjustments (16) and Guest Laundry Pickup/Drop to Rooms (15) suggest that hotels recognize the potential of smart room automation and service robots to enhance guest comfort. AI-driven energy management can optimize power usage, reducing operational costs, while autonomous laundry services could improve convenience and efficiency in larger hotels.

4. **Operational Task Automation**

    Organizing Cleaning Schedules (15) and Digital Checklists with Real-Time Updates (14) indicate that task management automation is seen as beneficial but slightly less prioritized than physical cleaning. While AI-driven housekeeping management can improve workflow and efficiency, some hotels may still rely on human supervision for final decision-making.

The sample indicates that hotels are considered a good fit for Fully Autonomous Systems (FAS), particularly in areas where tasks are repetitive, labour-intensive, and require minimal guest interaction. Many respondents highlight that housekeeping, public area cleaning, linen

delivery, and other back-of-the-house operations are well-suited for automation. The primary benefits include workload reduction, increased efficiency, cost savings (overtime reduction), and faster operations, especially during peak occupancy periods. However, a recurring concern is that guest-facing areas should retain human interaction, as personalized service remains a key expectation for travellers, particularly in India. Some responses emphasize that hotels must tailor automation systems to their unique operational needs, ensuring seamless integration with existing workflows. There is also a strong sentiment that housekeeping, as a traditionally labour-intensive department, stands to benefit significantly, enabling staff to focus on guest personalization rather than routine cleaning tasks. Overall, while FAS can enhance operational efficiency and manpower optimization, its adoption must be strategically implemented, balancing automation with human touchpoints to maintain the hospitality experience.

The data collected also indicates that the primary challenges in adopting Fully Autonomous Systems (FAS) in the housekeeping department revolve around high costs, staff adaptability, infrastructure requirements, and guest acceptance.

1. *High Initial Investment & Maintenance Costs*
   Many responses highlight that the upfront cost of purchasing, installing, and maintaining these systems is a significant barrier. Hotels, particularly standalone properties and budget hotels, may struggle with the financial burden of FAS adoption, making it more viable for luxury or chain hotels with larger budgets.

2. *Staff Training & Adaptation Issues*
   Many respondents express concerns about associates struggling to understand and operate new technology and the need for extensive training programs. The hospitality industry relies on a largely manual workforce, and the transition to automation may require dedicated training, SOPs, and gradual integration to ensure seamless operations.

3. *Job Displacement & Workforce Concerns*
   Some responses suggest that automation could reduce hiring needs, leading to fewer job opportunities for housekeeping associates. While automation can reduce workload, the human touch in hospitality is irreplaceable. A balanced approach that integrates FAS alongside human workers rather than replacing them may be a more sustainable solution.

4. *Guest Experience & Acceptance*
   Several respondents note that guests may not prefer machines over human service, particularly in a service-driven industry like hospitality. While back-of-house automation (cleaning, linen delivery, and logistics) is widely accepted, front-of-house automation (guest-facing roles) may require careful consideration to avoid a loss of personalized service.

5. *Operational & Infrastructure Limitations*
   Some concerns revolve around space constraints, power consumption, and system malfunctions that could disrupt daily operations. Hotels need to assess infrastructure compatibility before implementing FAS, ensuring that space, power backup, and maintenance resources are in place to support long-term sustainability.

Findings
❖ *Perceived Benefits of Fully Autonomous Systems (FAS)*
- *For Guests*:
  - Majority of respondents agree that FAS enhances the guest experience by ensuring efficiency, accuracy, and consistency in service.
  - A few respondents remain neutral, suggesting that while automation is beneficial, it cannot fully replace human hospitality.
- *For Housekeeping Staff*:

- o Increased efficiency and reduced workload were the most cited benefits (21 mentions each).
  - o Technology upskilling (20 mentions) and career development (12 mentions) indicate a shift towards automation-driven learning and job adaptation.
  - o Respondents recognize that FAS can improve ergonomics and job satisfaction, reducing physical strain on housekeeping associates.
- For the Hotels:
  - o Improved service consistency (21 mentions) and reduced human error (22 mentions) highlight FAS's potential to streamline operations.
  - o Other key benefits include environmental sustainability (reduced chemical usage), higher guest satisfaction, and attracting tech-savvy travellers.

❖ ***Housekeeping Tasks Best Suited for Automation***

- Housekeeping tasks with repetitive and predictable processes were identified as most suitable for automation.
- Top tasks include:
  - o Room Vacuuming & Mopping (20 mentions)
  - o Exterior Window Cleaning (20 mentions)
  - o Lawn Maintenance (20 mentions)
  - o Linen Delivery (19 mentions)
  - o Public Area Sweeping & Mopping (18 mentions)
- Tasks involving guest interaction, personalized service, and decision-making were seen as less suitable for automation.

❖ ***Challenges in Adopting Fully Autonomous Systems***

- *High Capital & Maintenance Costs:*
  - o The most frequently cited challenge is the high initial investment required for automation, including procurement, installation, and maintenance.
  - o Budget constraints, especially for standalone and mid-scale hotels, were noted as a key adoption barrier.
- *Staff Training & Adaptation Issues:*
  - o Respondents raised concerns about staff not being tech-savvy, requiring significant training and reskilling programs.
  - o Some feared that machine malfunctions could disrupt operations if staff are not adequately trained to troubleshoot them.
- *Workforce Reduction & Job Security Concerns:*
  - o There is concern that automation might lead to job losses in the housekeeping department, reducing the workforce demand.
  - o However, others see it as an opportunity for job transformation, requiring new roles in maintenance and FAS management.
- *Guest Experience & Acceptance:*
  - o Many respondents emphasized that guests value personalized service, and automation should not replace human interactions entirely.
  - o Luxury and boutique hotels may struggle with FAS integration in guest-facing areas, while business hotels may adapt more easily.
- *Infrastructure Limitations:*
  - o Concerns were raised about the space, power requirements, and operational challenges of fully integrating FAS in hotels.
  - o Some hotels may lack the necessary infrastructure to support autonomous systems, making integration difficult.

❖ *Correlation Between Hotel & Housekeeping Perspectives on FAS*
- Both housekeeping staff and hotel management acknowledge that FAS can improve efficiency and service consistency but differ in concerns:
  - Housekeeping staff focus on workload reduction and ease of operations but worry about job displacement and adaptability.
  - Hotels prioritize cost, return on investment (ROI), and guest experience, ensuring that automation does not negatively impact service quality.

Suggestions

The implementation of Fully Autonomous Systems (FAS) in the hospitality industry represents a strategic shift towards operational efficiency, resource optimization, and technological advancement. As the industry embraces automation in alignment with global trends, integrating FAS within hotel operations can significantly enhance productivity while reducing resource wastage. By embedding automation at the core of specific housekeeping and operational processes, establishments can achieve seamless, cost-effective, and precision-driven service execution. Moreover, FAS presents a unique opportunity to cater to a growing demographic of tech-savvy travellers who seek innovative and technologically integrated service experiences. However, for such adoption to yield meaningful outcomes, automation must go beyond surface-level applications and be strategically embedded into the operational framework.

One of the key advantages of FAS adoption lies in workforce upskilling, employee retention, and improved work-life balance. Automation can alleviate the physical strain on housekeeping staff, allowing them to focus on higher-value guest interactions and personalized services, ultimately leading to enhanced job satisfaction. Additionally, FAS contributes to improved guest experiences by ensuring service consistency and minimizing human error. However, these benefits can only be fully realized through structured maintenance programs and comprehensive training modules for hotel associates to ensure smooth integration and optimal system utilization.

Given the substantial initial investment required for automation technologies, maximizing their operational efficiency is imperative. Deploying these systems in a 24x7 operational framework ensures a higher return on investment, making them cost-effective over time. FAS exhibits adaptability across various surfaces, including tiled floors, carpets, and outdoor spaces, making them a versatile asset for hotel environments. While maintenance costs are a critical factor in long-term feasibility, a hybrid approach—wherein major technical concerns are managed through contractual agreements with manufacturers while routine maintenance is handled by in-house personnel—can effectively mitigate financial and resource-related challenges.

Addressing security and privacy concerns is paramount in the adoption of FAS, particularly in guest-centric areas. Hotels can mitigate risks by procuring autonomous systems that rely solely on sensor-based navigation, eliminating the need for active cameras. Implementing stringent policies to ensure no data is transmitted or recorded further reinforces data security and guest privacy. Among the various applications, vacuuming, mopping, and automated linen delivery robotics are the most viable for immediate integration, as they align seamlessly with existing hotel operations. To maximize the potential of FAS, structured training programs for all associates must be prioritized, ensuring efficient system utilization and minimizing unintended operational disruptions. Through a well-planned approach, FAS can transform hotel housekeeping, driving efficiency, cost-effectiveness, and superior guest service.

Conclusion

The integration of Fully Autonomous Systems (FAS) in the housekeeping operations of the hospitality industry presents a transformative opportunity to enhance efficiency, optimize resources, and improve overall service quality. This study aimed to evaluate the feasibility, benefits, and challenges associated with the adoption of FAS in hotel housekeeping. Key findings indicate that automation can significantly reduce manual workload, improve productivity, and minimize human errors, leading to a more seamless guest experience. Additionally, FAS can contribute to operational cost savings in the long run by streamlining housekeeping processes such as vacuuming, mopping, and linen delivery. However, challenges such as high initial investment, maintenance costs, training requirements, and privacy concerns must be addressed through strategic planning and structured implementation. The study also highlights that automation should complement human efforts rather than replace them entirely, ensuring that personalized service – an essential aspect of hospitality – is maintained.

Looking ahead, future research should explore the long-term cost-benefit analysis of FAS implementation across different hotel segments, including luxury, midscale, and budget properties. Additionally, further studies can investigate the impact of automation on employee roles and job satisfaction, examining how upskilling initiatives can enhance workforce adaptability. Another critical area of research involves assessing guest perceptions and acceptance of autonomous housekeeping solutions, particularly in culturally diverse markets. Technological advancements, such as AI-driven predictive maintenance and IoT integration, also present opportunities for further exploration. Furthermore, research into sustainable automation solutions, such as energy-efficient robotics and eco-friendly cleaning technologies, could align FAS adoption with environmental sustainability goals. By addressing these areas, future studies can provide a more comprehensive framework for hotels to navigate the transition towards automation while balancing efficiency, cost-effectiveness, and guest satisfaction.

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