Title

SMART ATTENDANCE AND WORKFORCE ANALYTICS SYSTEM

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ABSTRACT

Workforce management in Malawi remains largely paper-based, with manual attendance registers, informal leave records, and weak supervision structures that undermine productivity and institutional accountability. This paper presents AttendIQ, a Smart Attendance and Workforce Analytics System designed for the operational realities of Malawian organizations. The system integrates biometric face recognition with real-time attendance logging and overtime tracking. It is deployed on a hybrid on-premise and cloud architecture that sustains full functionality during internet outages, a critical requirement for district-level institutions. A role-based access control (RBAC) framework mirrors Malawi's hierarchical workplace structures across three roles: Employee, Supervisor, and HR Officer. An embedded machine learning layer using XGBoost and Scikit-learn detects anomalies such as buddy punching, GPS spoofing, and habitual absenteeism, surfacing findings through an interactive interface with confidence scores and recommended actions. Delivered as a single-file, browser-executable application requiring no installation, AttendIQ is immediately deployable across diverse organizational settings. The system aligns with the Malawi Growth and Development Strategy (MGDS III) and the national e-Government strategy, and supports integration with regional payroll platforms, including Sage. The study adopts a design-science approach, combining system development, usability evaluation, and simulated anomaly-detection testing to assess functionality, reliability, and user acceptance. Preliminary evaluation indicates that AttendIQ canreduce manual record-keeping, strengthen supervision, improve data accuracy, and support evidence-based workforce planning. The paper also discusses implementation considerations, including data privacy, biometric consent, infrastructure constraints, staff training, and institutional adoption. Future work will extend the system with payroll integration, offline synchronization enhancements, accountability dashboards and predictive workforce analytics.

Keywords: Smart Attendance, Workforce Analytics, Facial Recognition, Biometric Authentication, Buddy Punching, Liveness Detection, Role-Based Access Control (RBAC), Anomaly Detection, Leave Management, Web-Based System, Malawi.

INTRODUCTION

Background of Study

Attendance monitoring is a fundamental component of operational efficiency, accountability, and optimal resource allocation within organizations *(Salunkhe et al., 2025).* Attendance systems allow employers to monitor employees' working hours and to track late arrivals *(Firdaus Ngah & Abdullah, 2024).*

Automated attendance systems that employ facial detection and recognition have been developed and implemented in diverse settings, including educational institutions, workplaces, and event venues. These systems use biometric data, specifically facial features, to identify individuals and record attendance, and they deliver greater accuracy and efficiency than conventional methods such as manual sign-in sheets or verbal roll calls *(Jha et al., 2023).*

The Smart Attendance and Workforce Analytics System is a web-based solution designed to automate and strengthen an organization's workforce management processes. It supports instant automated logging, leave management, observation of performance trends, and the generation of reports that summarise productivity and performance. Through data visualisation and interpretation, organizations can trace how employees are performing, identify individuals who deserve recognition, and plan for future human resource needs.

In many settings there is still no proper system for monitoring employee attendance, and some companies continue to keep paper-based records *(Olagunju et al., 2018).* In developing countries such as Malawi, most organizations have limited access to automated workforce analysis tools, unreliable audit trails, and a systematic lack of data-driven workforce insight. This highlights the need for an accessible and affordable workforce analytics system that helps organizations manage their human resources better. By adopting modern technologies and easy-to-use platforms, the system promotes human resource management awareness and strengthens discipline within organizations.

Automated attendance systems based on facial detection and recognition therefore represent a significant step towards streamlined and intelligent attendance management *(Jha et al., 2023).* With increasingly widespread access to web-enabled technologies, digital human resource

management tools can reach many more organizations. By combining leave management, facial recognition logging, and visual analytics, the system simplifies management while nudging behaviour towards greater productivity. The facial recognition feature also makes the system suitable for marginalised groups, for instance employees with disabilities.

RESEARCH OBJECTIVES

Reliance on manual attendance and workforce records presents several problems. These methods are time-consuming, unreliable, and insecure because they depend on manual input and tracking, which is not always feasible, especially in large organizations, and they are prone to inconsistency caused by human fatigue or negligence. The main objectives of this study are to:

- Streamline leave and overtime management
- Automate attendance capture
- Prevent buddy punching and fraud
- Generate reliable data for payroll and compliance
- Centralise workforce visibility.

SYSTEM DESCRIPTION

The system is an information platform created to let users track, monitor, and regulate organizational workforce activity systematically and effectively. It automates attendance and performance monitoring, manages leave transparently, and gives users up-to-date employee information through an intuitive interface. By integrating human resource information, it removes the inefficiencies and errors of manual, hand-written record-keeping and gives users a clear visual picture of workforce status through reports and dashboards.

Users benefit from scheduled automation such as performance monitoring and leave monitoring, together with analytical tools that show trends useful for future planning. The platform also provides data security and data backup to prevent data loss, and it is designed for web access with simple navigation so that even the least technical users can use it.

Overall, the system empowers organizations to make informed, performance-based decisions, instil discipline, and develop a high-performance culture by converting raw workforce data into timely, insightful information that addresses the daily needs of human resource management.

LITERATURE REVIEW

Published research on smart attendance systems in Malawi remains limited, particularly in attendance tracking and workforce analytics. Some attendance monitoring initiatives have been implemented in the education sector, but the overall evidence base is small compared with that of developed countries. This shows the need to explore and develop a smart attendance system that fits the Malawian context.

Facial recognition technology has evolved significantly since its early development in the 1960s, when systems relied mainly on geometric measurements of facial landmarks *(Hamie, 2025).* Facial recognition is widely used in security, authentication, verification, and surveillance, and many businesses rely on it *(Pradyumna et al., 2023).* Today, facial-recognition-based attendance systems can automate attendance tracking and workforce analytics, reducing manual work and improving accuracy. They help address common challenges such as buddy punching, manual entry errors, limited real-time access to attendance records, and the need for reliable proof of identity and location *(El-mawla et al., 2022; Kalita & Bhagawati, 2024).* Facial recognition therefore presents a promising approach for improving attendance management in Malawi. A fully automated web-based attendance system also makes it easier to monitor daily activities and manage records efficiently *(Nadhan et al., 2022).*

Summary of reviewed literature

Author(s)	Focus and key finding	Gap and relevance
Hamie (2025)	Facial identification and law-enforcement support; identifies education as the main domain of smart attendance adoption.	Very little research in Malawi and little on workforce analytics. Confirms the gap that justifies a locally tailored solution.
Pradyumna et al. (2023)	Smart attendance using face recognition; shows it can be adapted to low-	No evidence of deployment in Malawian workplaces. Provides design

	resource environments.	cues for context-sensitive implementation.
El-mawla et al. (2022)	Attendance using QR code, fingerprint and face recognition; shows accuracy, fewer errors and real-time verification.	Developed-country settings; not evaluated for Malawi. Technical foundation for the facial recognition module.
Kalita & Bhagawati (2024)	Biometric attendance; effectively eliminates proxy attendance and improves integrity.	No analysis of workforce analytics or organizational impact in Malawi. Supports the anti-buddy-punching objective.
Nadhan et al. (2022)	Smart attendance monitoring for Industry 4.0; real-time verification improves accuracy and security.	Largely unexplored for Malawian organizations. Justifies developing and evaluating a local system.

SYSTEM ANALYSIS

This section gives an overview of current attendance and workforce analysis practice among organizations, highlighting realities in Malawi where technological advancement and digital literacy are still developing. It also sets out the key issues the proposed system addresses: buddy punching, manual entry errors, limited real-time access to attendance records, and the lack of reliable proof of identity and location.

Research has found that most organizations in developing countries depend on casual or manual methods of monitoring attendance, which leads to poorer human resource decisions, weak planning, and poor forecasting of future needs. In Malawi, many organizations face difficulties with work planning, forecasting, and employee time-keeping behaviour despite repeated interventions to encourage discipline. These practices point to the need for low-cost, compact digital tools designed to improve attendance and workforce analysis.

PROBLEM DEFINITION

Many organizations, especially in developing countries, still depend on manual or ad-hoc methods such as paper-based registers, notebooks, and simple spreadsheets to manage attendance. These approaches suffer from inaccurate and incomplete records, which lead to poorly informed attendance and workforce decisions. The manual process is time-consuming and prone to human error, and users struggle to consolidate and summarise attendance data meaningfully. Without timely and clear summary reports, organizations cannot visualise attendance patterns or staffing trends, which limits their ability to plan work or identify employees to reward.

Forecasting future staffing needs, such as leave management plans, becomes difficult without analytical tools. Other prevalent problems include the risk of data loss through lack of backups, limited data security, and low accessibility for less tech-savvy users who find digital tools complex or intimidating. These problems show an urgent need for an accessible attendance and workforce analytics system that mitigates these weaknesses and promotes better-informed decisions.

EXISTING SYSTEM

Attendance and workforce practices today are highly varied, ranging from paper records and notebooks to generic spreadsheet templates. Spreadsheets offer some flexibility, but their usefulness is limited by the technical expertise they demand. Many are not configured to handle recurring transactions or to project staffing schedules over the long term. Commercial attendance software, in contrast, is often feature-rich and tailored to heterogeneous staffing needs, but it can be too sophisticated for average users, usually requires continuous internet connectivity, and is seldom customisable to local organizational and regional staffing practices.

This sophistication, combined with a lack of contextualisation, discourages adoption in developing nations. Most existing implementations also fail to account for the staffing behaviour and constraints of low-resourced settings with limited digital expertise. This points to the need for a user-friendly attendance and workforce analytics solution designed around the behaviour, digital literacy, and technology access of intended users in Malawi and comparable settings.

PROPOSED SYSTEM

The proposed Smart Attendance and Workforce

Analytics System is an automated, web-based solution that addresses the limitations of traditional methods and supports efficient attendance and workforce analytics, especially for organizations in developing countries such as Malawi. It helps organizations take control of staffing by recording daily attendance, organizing departments into categories, creating and tracking schedules, monitoring leave, and producing clear summary reports with visual charts.

At its core are user authentication and profile management, which protect the privacy and security of user data. Key features include secure login and personalised profiles, facial recognition, easy entry of leave requests with automatic categorisation, an intuitive dashboard with graphs and charts that visualises real-time and historical attendance data, and reliable backup and restore functions. Data is held in a secure database for retrieval and editing.

SYSTEM OBJECTIVES

The main goal is a dependable, user-friendly system that allows organizations to accurately record, analyse, and report on attendance and workforce data. Beyond this, the system aims to improve how organizations plan and predict staffing needs; make attendance patterns clear through visual reports and summaries; keep user data secure with reliable backups and seamless access across devices; and provide an affordable, practical solution tailored to local needs.

- **Feasibility Study:** The feasibility study examines the technical and operational viability of the system to establish whether the project is practical and ready for implementation.
- **Technical feasibility:** The system is built with widely available open-source technologies that can support a robust attendance and analytics application. Open-source frameworks and libraries reduce development time and cost, and the system can be deployed on ordinary hardware such as desktop computers, laptops, and even mobilephones, so it suits small organizations and needs no special or costly equipment. The assessment considered whether existing infrastructure, including hardware and web and mobile platforms, can support the system; how easily it can be developed; compatibility with existing tools; data security; and backup functions, so that attendance recording and report generation run dependably.
- **Operational feasibility.** The system is easy to deploy and operate. With simple interfaces and automated data collection it reduces dependence on skilled operators. Once installed it functions largely autonomously, and users need only basic training to interpret the data or enter data through the dashboard. Maintenance is straightforward and mostly limited to occasional system resets. Its reliability and accuracy allow users to interpret data and make sound staffing decisions.

FINDINGS AND RECOMMENDATIONS

Limited real-time attendance tracking leads to poor workforce planning and inaccurate forecasting of staffing needs, which creates operational challenges. When management prepares employee schedules, the absence of timely attendance data makes it difficult to allocate staff effectively. Likewise, the lack of accurate, automated attendance records can lead to data loss, inefficient decisions, and potential financial losses. Timely, accurate, and automated attendance tracking is therefore essential for workforce efficiency and organizational planning.

Based on these findings, it is recommended that organizations adopt automated attendance capture with biometric identity verification, centralise attendance and leave records in a secure database with regular backups, provide dashboards that visualise attendance and leave trends in real time, and design interfaces simple enough for users with limited digital literacy.

SYSTEM SPECIFICATION

Hardware (client side). A webcam is required for facial recognition, together with a dual-core processor of 2.0 GHz or faster, 4 GB of RAM, at least 20 GB of free storage for application files and growing attendance records, and a screen resolution of 1024 × 768 or better so that dashboards, charts, and reports display clearly. Internet connectivity is recommended for cloud backup and synchronisation, but the system can still function offline for organizations without reliable connectivity.

Hardware (server side). For web or centralised deployment, a server with at least 2 virtual

CPU cores, 4–8 GB of RAM (more for many concurrent users), and 50 GB or more of solid-state storage with provision for regular backups is recommended. Recommended operating systems are Linux Ubuntu
20.04 or later, or Windows Server 2019 or newer.

Software. Users need only a modern web browser such as Chrome, Firefox, or Edge. The backend is developed in PHP, chosen for its flexibility, maintainability, and support for modular feature addition. MySQL stores attendance records securely with fast access, and a web server such as Apache handles incoming requests. The frontend uses HTML5 for structure, CSS3 for styling, and JavaScript for interactivity, while Chart.js generates charts and graphs of attendance patterns and staff performance. Development uses Git for version control and Visual Studio Code as the editor, with unit and integration tests to verify each feature. Attendance data can be exported in familiar formats such as CSV or Excel, and automated scheduled backups protect against accidental data loss.

SYSTEM DESIGN

System design is the blueprint for the structure of the Smart Attendance and Workforce Analytics System, covering hardware, software, and data flow. It converts functional requirements into an architectural layout of components, their operations, and their interfaces. The system is modular, consisting of attendance tracking, face ID management, leave management, reporting, and login modules.

SYSTEM ARCHITECTURE

The architecture follows industry-standard design patterns and uses a three-tier design that separates concerns, so that each layer can be designed, tested, and updated independently (Figure 1).

Users: Employee | Supervisor | HR Officer

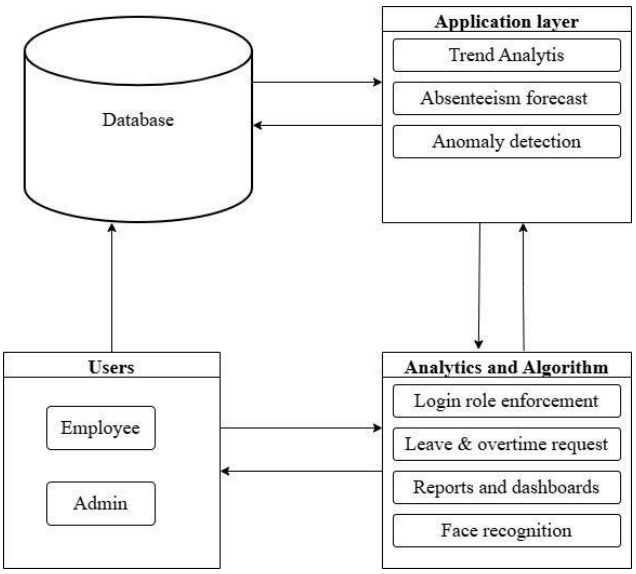


Figure 1: System architecture

Presentation Layer (Frontend)

This is the part of the system that users see and interact with. It is built with HTML5 for page structure, CSS3 for clear and professional styling, and JavaScript for interactive features that respond to user actions. Chart.js turns attendance data into easy-to-understand graphs and charts that update in real time. The layer displays the user interface clearly; checks that user input makes sense before it is sent to the server; communicates with the backend through API calls to retrieve or save data; converts raw attendance data into visual representations; adjusts its layout automatically to different screens; and keeps track of user sessions so that people stay securely logged in while they work.

Application Layer (Backend)

The backend is implemented in PHP. It develops and manages RESTful API endpoints for client–server communication and implements the business logic that governs application behaviour. It enforces authentication and authorisation for secure access, produces reports for attendance insights and summaries, performs analytics calculations that yield trends and interpretations, and provides error handling and logging to maintain stability and support debugging.

Data Layer (Database)

The database uses MySQL 8.0 or later. It provides continuous storage of all application data across multiple entities; enforces data integrity through

constraints and validation; manages transactions to preserve ACID properties; implements backup and recovery mechanisms to prevent data loss; applies query optimisation to improve response times; and enforces relational integrity through foreign keys so that no orphaned records remain.

Data moves through the layers as follows: the user inputs data through the dashboard; the application layer (PHP) receives and processes it; PHP communicates with MySQL; MySQL completes the processing and returns the result to PHP; and the formatted data travels back through the API endpoint to the frontend.

Data Flow

The data flow design shows how data moves through the system and how processes transform it between components, from user input to user visualisation, across software and storage components.

Employee flow

To submit a leave request, the employee enters data into the dashboard. The presentation layer performs client-side validation and sends an HTTP request to the application layer, which forwards it to PHP for identity authentication and business-logic validation. Once validated, the application layer categorises the transaction as a leave request using predefined rules and issues an SQL query to store it. The data layer enforces integrity constraints, executes the transaction, and confirms completion. The application layer then calculates the updated leave balance, updates the employee's account, formats the response as JSON, and returns it to the presentation layer. The dashboard refreshes and Chart.js renders a real-time graphical view of leave usage and remaining balance.

Administrator (HR Officer or Supervisor) flow

The administrative process follows the same architecture but is initiated by an HR Officer or Supervisor who reviews, approves, or manages leave and attendance records. Actions such as approving a leave request or generating a report are validated client-side before being sent to the application layer, which forwards them to PHP for credential authentication and role-based permission checks.

The application layer then classifies the action as an approval, a rejection, or a request for aggregated workforce data, and queries MySQL to update records or retrieve attendance and leave data. After the data layer confirms execution, affected records, such as adjusted leave balances, are recalculated, and the JSON result updates the administrator's dashboard. Chart.js renders attendance trends, leave balances, and organizational anomalies for visual monitoring.

SYSTEM TESTING

System testing validates that the entire system functions according to its specified requirements and that all components developed in earlier stages work together accurately, reliably, and efficiently in a real-world environment. It determines whether the implemented features run properly, including those that required changes to the database structure to meet user requirements *(Sulistyo et al., 2023).* Testing aims to detect defects, verify compliance with user requirements, and confirm that functions such as user authentication, attendance recording, leave management, reporting, and data backup operate as expected. Both manual and automated techniques were used, in accordance with the project's design specifications. The test plan defines the approach, tools, environment, test cases, expected outcomes, and success criteria.

Functional Testing

Functional testing, also known as black-box testing, assesses the functionality of a system by validating its output on sets of targeted test *cases (Röttger et al., 2021).* It began with requirement analysis: a requirement is a property that must be exhibited in order to solve a real-world problem, and requirements analysis includes classification, conceptual modelling, architectural design, allocation, and negotiation *(IEEE Computer Society, 2001).* High-level test planning then fixed the environment, schedule, and team before test cases were written, so that unit, integration, regression, and non-functional testing could be performed before delivery *(Obaid Barraood et al., 2021).* Test cases were developed with defined inputs, such as valid and invalid login credentials, and expected outputs, such as successful login, in an environment of devices, server, and databases mirroring deployment. The functional test types were:

- **Positive testing:** verifies correct behaviour under normal conditions, such as valid logins and report generation.

- **Negative testing:** checks the response to invalid input, such as a wrong password or values outside predefined constraints.
- **Boundary testing:** examines edge cases, such as login attempts after session timeout.

Usability and Security Testing

Usability testing evaluates the ease of using and learning the system and its documentation, the effectiveness of the system in supporting user tasks, and the ability to recover from user errors *(IEEE Computer Society, 2001).* For this system it focuses on how easily employees and other users interact with the interface, understand the data, and act on it. Security testing ensures that only authorised users can access the system, that data are protected, and that sensitive operations such as login are secure.

Performance Testing

Performance testing helps identify resource-intensive operations and optimise them for better efficiency *(Ramachandran, 2023).* The procedure is to define key metrics such as response time; prepare a test environment that mimics real operating conditions; design scenarios that simulate normal use and multiple simultaneous logins; execute tests under different load levels while monitoring errors; monitor CPU, memory, network bandwidth, and storage to identify bottlenecks; compare observed performance with benchmarks; and document issues, optimise, and retest. The types of performance testing considered were:

- **Load testing** proves that the application operates under heavy usage (Kakolu & Faheem, 2023).
- **Stress testing** checks behaviour under sudden spikes in user activity, which can cause slowdowns or crashes if the application is not optimised (Kakolu & Faheem, 2023).
- **Scalability testing** evaluates how well the system scales as devices or users are added.
- **Stability testing** assesses reliability and resource usage over prolonged operation.

Performance testing ensures that the system is responsive and reliable and provides the timely and accurate information that effective attendance and workforce management depends on.

Integration Testing

Integration testing assesses the interactions among modules. Unlike unit testing, which tests individual code units in isolation, it evaluates how components perform when integrated into a coherent system *(Torino, 2023).* For this system it ensures that hardware and software components work together from the dashboard to the database. The procedure is to identify module interfaces, such as data passing from the dashboard to the database; prepare realistic test data; define test cases specifying inputs, expected results, and conditions *(Torino, 2023);* deploy the modules on a test server that mimics real deployment; run the test cases step by step while observing interactions; and record results, then fix, retest, and report any issues. Three integration strategies were considered: top-down (starting from the top-level module and integrating downwards), bottom-up (starting from lower-level modules and integrating upwards), and big bang (integrating all modules at once). System testing then covered the entire integrated system including external dependencies *(Wang et al., 2024).*

SYSTEM IMPLEMENTATION

The implementation phase translated the design specifications and development work into a working application, integrating all modules and deploying the system in a test environment before final production release. Each component was developed independently and then integrated into the complete system. The main user-facing screens are described below.

- **Login page.** The entry point for all users, where credentials are verified and role-based access control determines the permissions granted.
- **Dashboard after successful login.** Loads with the user's data and presents real-time information appropriate to the user's role.
- **Facial recognition.** Uses the device webcam to identify the employee for check-in and check-out, supporting the objective of preventing buddy punching.
- **Leave application.** Lets employees submit leave requests, which supervisors approve or reject and which update leave balances.
- **Workforce dashboard.** Presents attendance and leave data as charts and summaries for monitoring workforce trends.

DISCUSSION AND IMPLEMENTATION CONSIDERATIONS

The results of testing show that the core modules, login, dashboard, and reporting and charting, work as expected and integrate correctly. Preliminary evaluation suggests that the system can reduce manual record-keeping, strengthen supervision, improve data accuracy, and support evidence-based workforce planning.

Several considerations affect real-world adoption. Biometric data are sensitive, so data privacy and informed biometric consent must be addressed before facial recognition is deployed. Infrastructure constraints, notably unreliable internet connectivity at district level, make offline operation and later synchronization important. Staff training and institutional readiness influence whether users trust and adopt the system, and the platform is intended to remain simple enough for users with limited digital skills. Finally, because facial recognition can serve employees who cannot use other input methods, the system can contribute to the inclusion of marginalised groups such as people with disabilities.

RECOMMENDATIONS

Organizations considering the system are advised to begin with a pilot in one department or site, so that staff can become familiar with check-in, check-out, and leave procedures and so that early problems can be corrected before full rollout. Short, practical training sessions for employees, supervisors, and HR officers will reduce resistance and errors, particularly for users with limited digital experience. Management should confirm that each site has a working webcam, adequate lighting, and a reliable power supply, and should plan for periods without internet access by relying on the system's offline capability and scheduled synchronisation.

Institutions should also define in advance how attendance records will feed into leave approval, overtime, and payroll processes, and who is accountable for reviewing reports. Finally, user feedback should be collected after launch and used to refine the system, in keeping with the iterative approach adopted in its development. Taken together, these steps help ensure that the technology strengthens supervision and accountability rather than adding administrative burden.

CONCLUSION

The Smart Attendance and Workforce Analytics System has been designed, developed, tested, and implemented to address the need for accessible attendance management tools in organizations, particularly in developing countries such as Malawi. It enables organizations to manage human resources through systematic tracking, informed planning, and insightful reporting. The project shows that thoughtfully designed technology can help organizations take control of their attendance and workforce management, particularly where access to auditable attendance records is limited, and that such tools can promote inclusion of marginalised groups such as people with disabilities. Its completion, from concept through design, development, testing, and deployment, provides a foundation for future work and shows the potential of technology to create positive social impact through improved attendance management.

LIMITATIONS OF THE STUDY

The findings should be read with several limitations in mind. Evaluation to date is preliminary: testing covered the login, dashboard, reporting and integration flows, and anomaly detection was assessed through simulation rather than prolonged live deployment. The literature available on attendance systems in Malawi is itself limited, so comparisons rely largely on studies from other settings. The system also depends on a webcam and adequate lighting for facial recognition, and its biometric features require clear consent and data protection arrangements before wider rollout. Larger field trials across different types of organization would strengthen the conclusions.

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