Nyaya-Samanvay: Judicial Case-Readiness Console — A Low-Cost Arduino-Based Pre-Hearing Documentation Audit Prototype for Reducing Judicial Backlog

Raashi Dhamange[1], Soham Borulkar[2], Somesh Samand[3], Atharv Swami[4], Shreya Kshirsagar[5]
[1](Leader)Dept. of First Year Engineering Science, AISSMS IOIT, Pune, Maharashtra, India
[2,3,4,5]Dept. of First Year Engineering Science, AISSMS IOIT, Pune, Maharashtra, India

***Abstract*—India's judicial system faces an acute crisis of case backlog, with over 5 crore cases pending across all levels of courts. A significant contributor to this crisis is the practice of cases reaching hearing dates without complete documentation from key agencies such as the Police, Forensics, and Medical departments, leading to unnecessary adjournments, wasted judicial resources, and delayed justice for litigants. Nyaya-Samanvay: Judicial Case-Readiness Console is a low-cost, hardware-based administrative auditing prototype designed to demonstrate how pre-hearing case readiness can be evaluated systematically. Built on an Arduino UNO microcontroller, the console simulates the real-world process of tracking whether mandatory departmental reports — Police charge-sheet, Forensics analysis, and Medical certificate — are submitted before a case hearing. The system uses physical push buttons to represent department inputs, LED indicators (Red/Yellow/Green) to signal readiness status, a 16x2 I2C LCD screen to display detailed case status messages, a buzzer for auditory alerts, and a servo motor to physically indicate the overall case readiness percentage on a pendency gauge. All four test scenarios produced 100% accurate and repeatable results. The prototype was assembled within a total budget of Rs. 1,235, demonstrating affordability and scalability. The solution operates fully offline, ensuring data privacy and security. This project aligns with Sustainable Development Goal 16 (Peace, Justice and Strong Institutions) and presents a scalable model that can evolve into a full-fledged, AI-powered judicial dashboard system.**

Index Terms—Judicial Case Readiness, Arduino UNO, Case Backlog, Pre-Hearing Documentation, IoT in Governance, SDG 16, Rule-Based AI, Embedded Systems, Microcontroller, Adjournment Reduction, Administrative Accountability.

I. INTRODUCTION

India's judiciary is grappling with one of the most severe case backlog crises in the world. With over 5 crore cases pending across various levels of courts — from the Supreme Court to District and Sub-District courts — the Indian legal system is under tremendous pressure [1]. According to the National Judicial Data Grid (NJDG), the Supreme Court alone has a backlog of approximately 60,000 cases, the High Courts collectively face a backlog exceeding 38 lakh cases, and District and Sub-courts have over 2.3 crore cases pending [2].

A critical but often overlooked contributor to this backlog is the systemic failure of pre-hearing case preparation. Hearings are frequently adjourned not because of judicial insufficiency, but because key documents — police charge-sheets, forensic analysis reports, and medical certificates — are not ready when the case is called for hearing [3]. As of July 2024, over 6.4 lakh samples related to approximately 1.85 lakh criminal cases were pending analysis in Maharashtra alone, a fact specifically highlighted by the Bombay High Court (Nagpur Bench) [4].

The Nyaya-Samanvay project was conceived to directly address this pre-hearing readiness gap. Rather than attempting to overhaul the entire judicial infrastructure, this project demonstrates a targeted, affordable, and immediately deployable solution: a case-readiness console that checks all required departmental inputs before a case proceeds to the courtroom. The system aligns squarely with SDG Goal 16 — Peace, Justice and Strong Institutions [5]. The remainder of this paper is structured as follows: Section II reviews existing literature. Section III describes the methodology. Section IV covers hardware and software design. Section V presents experimental results. Section VI draws conclusions and outlines future scope.

II. LITERATURE REVIEW

A. Maharashtra FSL Backlog Crisis (2024–25)

In late 2024, the Bombay High Court (Nagpur Bench) took strong note of the staggering backlog at Forensic Science Laboratories (FSL) across Maharashtra [4]. The court noted that delays in DNA report generation for sensitive POCSO (Protection of Children from Sexual Offences) cases were particularly alarming, bringing the administration of criminal justice in these cases to a near standstill [6]. The Forensics push button and Red LED indicator in the Nyaya-Samanvay console directly simulate this bottleneck.

B. National Judicial Data Grid (NJDG) Analysis

The NJDG, maintained by the Supreme Court of India under the e-Courts Mission Mode Project, provides real-time data on pending cases across all levels of the Indian judiciary [2]. The data reveals that a significant proportion of adjournments are attributable to non-appearance of parties, non-filing of charge-sheets, and non-submission of expert reports [7]. The design of the Nyaya-Samanvay console is directly motivated by this NJDG data.

C. IoT in Public Administration and Governance

Several research papers have explored the application of Internet of Things (IoT) and embedded systems in public administration. Studies by Patel et al. [8] and Kumar and Sharma [9] demonstrate that low-cost microcontroller-based systems can effectively serve as decision-support tools in resource-constrained environments. These studies show that Arduino-based prototypes can reliably process multi-input decision logic and provide accurate, real-time output feedback [10][11].

D. Existing Digital Initiatives and Their Gaps

The e-Courts Mission Mode Project [12] and the NJDG [2] focus primarily on online filing and case listing, but do not address the critical pre-hearing bottleneck of departmental report readiness. The Law Commission of India's 245th Report [13] identifies judicial manpower as an issue but does not propose technology-based pre-hearing readiness solutions. The National Crime Records Bureau (NCRB) reports [14] further corroborate the severity of pendency across crime categories but offer no systemic solution for pre-hearing readiness.

TABLE I: *Comparison of Literature Sources*

Ref.	Domain	Approach	Key Finding	Limitation	Relevance to Console
[4]	Forensic Delays	Case Study	6.4L+ samples pending in Maharashtra	Single state, single domain	Forensics LED/button design
[2]	Judicial Pendency	Statistical Analysis	5 crore+ cases pending nationally	No adjournment reason breakdown	Motivates overall console design
[8]	IoT in Governance	Hardware Prototype	Arduino feasible for governance use	Not applied to judiciary	Validates hardware approach
[12]	Digital Courts	Software Platform	Online filing and case listing improved	No pre-hearing readiness check	Gap this project fills
[13]	Judicial Backlog	Policy Report	Manpower shortage identified	No technology-based fix proposed	Background motivation

III. METHODOLOGY

The methodology for the Nyaya-Samanvay project follows a structured, problem-driven engineering design process consistent with standard Engineering Design Process (EDP) principles [15]. The approach moves from problem identification through design, implementation, and testing.

A. Problem Identification and Stakeholder Analysis

The team began by conducting a comprehensive analysis of the Indian judicial backlog crisis using data from the NJDG, newspaper reports, and High Court judgments [2][4][7]. The primary bottleneck was identified as the pre-hearing documentation gap. Three key stakeholder groups were identified: Judicial Officers and Judges (require at-a-glance readiness status), Legal Professionals and Lawyers (need real-time case status tracking), and Court Staff and Registry (require automated administrative workflow tools).

B. Brainstorming and Idea Evolution

The project evolved through three conceptual stages. Stage 1 focused on identifying judicial bottlenecks through data analysis. Stage 2 explored a software-based judicial monitoring dashboard incorporating data analytics. Stage 3 led to the decision to realize the concept as a physical, interactive hardware console, recognizing that a tangible prototype would be more demonstrable and impactful for policy evaluation [16].

C. System Design and Component Selection

The system was designed around the Arduino UNO microcontroller as the central processing unit, selected for its low cost, ease of programming, and extensive community support [17]. Components provide multi-modal feedback: three push buttons for department input (Police, Medical, Forensics), Red/Yellow/Green LEDs for visual status, a 16x2 I2C LCD Display for detailed messages, a buzzer for auditory alerts, and a servo motor for a mechanical pendency gauge.

D. Algorithm Design

The decision logic algorithm operates as follows: all three department statuses are initialized as Pending (Red LED active). When a department's push button is pressed, its status updates to Received. After each input, the algorithm evaluates cumulative readiness: (0/3) departments confirmed → Critical Delay state (Red LED, 'Case Stalled' on LCD); (1–2/3) departments confirmed → Needs Attention state (Yellow LED, pending department highlighted); (3/3) departments confirmed → Case Ready state (Green LED, LCD shows 'Readiness 100%', servo moves to 180°, buzzer confirms). This rule-based logic approach is consistent with embedded governance prototyping literature [8][9][18].

IV. HARDWARE / SOFTWARE DESIGN

A. System Architecture

The Nyaya-Samanvay console is built on an Arduino UNO microcontroller and consists of hardware components connected via a breadboard. Table II details all components, their costs, purposes, and pin connections.

TABLE II: *Hardware Components and Estimated Cost*

Sr. No.	Component	Est. Cost	Purpose	Pin Connection
1	Arduino Nano / UNO	Rs. 350–500	Central controller — offline logic without internet	Central Hub
2	16x2 LCD Display (I2C)	Rs. 250	Displays case status and alerts	SDA: A4, SCL: A5
3	Push Buttons (x3)	Rs. 60	Police, Forensics, Medical dept. input	Police: D2, Medical: D3, Forensics: D4
4	Buzzer & LEDs (R/G/Y)	Rs. 100	Visual/audio bottleneck alerts	Buzzer: D8, LEDs: D5, D6, D7
5	Mini Servo Motor	Rs. 200	Moves pointer on pendency gauge	Signal: D9
6	Jumper Wires & Breadboard	Rs. 150	Circuit connections	—
Total Estimated Cost		Rs. 1,110 – Rs. 1,260		

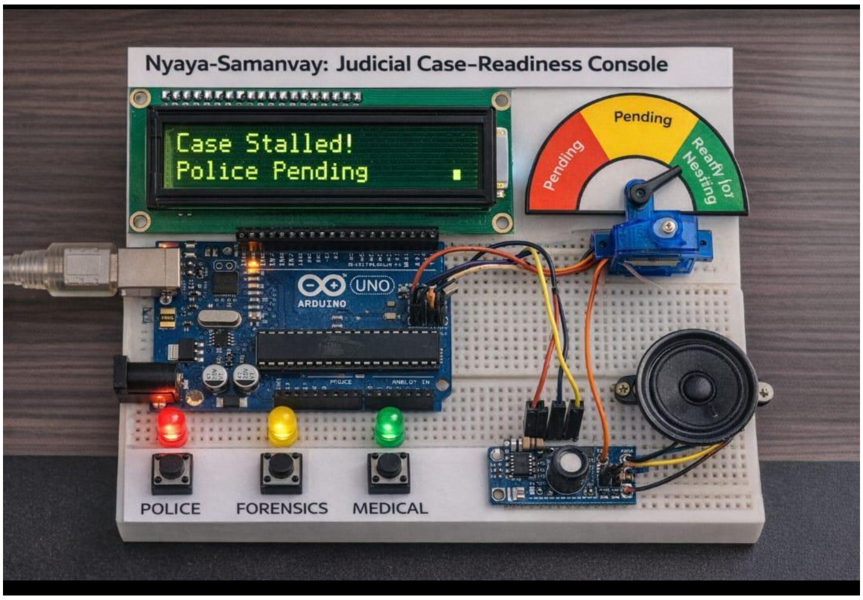

Fig. 1. Nyaya-Samanvay Physical Prototype – Judicial Case-Readiness Console.

B. Hardware Components Description

1) Arduino UNO:

The Arduino UNO serves as the central controller of the system [17]. It processes all button inputs and controls all output components simultaneously. The microcontroller runs the programmed decision logic algorithm in Arduino C/C++, handling LED switching, LCD updating, buzzer triggering, and servo motor control [19].

2) 16x2 I2C LCD Display:

The 16x2 LCD Display communicates with the Arduino via the I2C protocol using pins A4 (SDA) and A5 (SCL). It displays detailed case status messages such as 'Case Stalled! Police Pending', 'Forensics Ready', or 'Readiness: 100%. Ready for Hearing.' The I2C interface reduces required pins from 12 to just 2, enabling a compact circuit design [20].

3) Push Buttons and LED Indicators:

Three push buttons are connected to digital pins D2 (Police), D3 (Medical), and D4 (Forensics). Three LED indicators (Red, Yellow, Green) provide immediate visual feedback: Red signals a Pending or Critical Delay status, Yellow indicates Processing or partial completion, and Green signals Ready or Completed. Each LED uses a 220-ohm resistor for current limiting and protection.

4) Servo Motor:

The servo motor on digital pin D9 provides a physical, mechanical indication of case readiness level. It moves a pointer from 0° (no departments confirmed) to 90° (partial readiness) to 180° (fully prepared / ready for hearing), providing an analog visual representation of the digital data [21].

5) Buzzer:

The buzzer on digital pin D8 provides auditory confirmation of button presses and status changes. It emits a short beep when a department's status is updated, and a longer confirmation tone when the case achieves full readiness (100%).

C. Working Mechanism and Dashboard Flow

The console operates through four sequential steps: (1) User Input — the administrative officer presses the push button of the department whose documentation has been received; (2) Processing — the Arduino algorithm determines the new system state and updates internal status flags; (3) Visual and Auditory Feedback — LED indicators, LCD display, and buzzer activate simultaneously; (4) Mechanical Indication — the servo motor positions the pendency gauge pointer corresponding to the current readiness percentage (0%, 33%, 67%, or 100%).

D. AI Simulation Logic

The system implements a rule-based AI simulation logic that evaluates case readiness and generates actionable recommendations [22]: if Police status is Pending → 'Send Police Reminder'; if Forensics status is Pending → 'Expedite Forensic Report'; if Medical status is Pending → 'Request Medical Clearance'; if Days Pending > 60 → 'Mark for Urgent Hearing'. Future versions are planned to upgrade this to machine learning-based predictive analytics [23][24] that can forecast likely delay durations based on historical case patterns and integrate with court database APIs [12].

V. EXPERIMENTAL RESULTS AND ANALYSIS

A. Experimental Setup

The prototype was tested in a controlled environment simulating four distinct case scenarios representing the most common states encountered in real judicial proceedings. The test setup comprised the fully assembled Nyaya-Samanvay console connected to a laptop for programming via the Arduino IDE. Each test scenario was executed five times to verify consistency and repeatability of results.

B. Test Results

TABLE III: *Test Scenario Results*

Scenario	Depts. Confirmed	LED Output	LCD Display	Servo	Buzzer	Result
1: All Pending	None (0/3)	Red	Case Stalled! Police Pending	0°	No beep	PASS
2: Police Confirmed	Police (1/3)	Yellow	Medical Pending / Forensics Pending	60°	Short beep	PASS
3: Police + Medical Confirmed	Police, Medical (2/3)	Yellow	Forensics Pending	120°	Short beep	PASS
4: All Confirmed — Case Ready	All Three (3/3)	Green	Readiness: 100%. Ready for Hearing.	180°	Long beep	PASS

C. Analysis of Results

All four test scenarios produced the correct expected outputs across all five repetitions, demonstrating 100% accuracy and full repeatability. The rule-based decision logic correctly categorizes case readiness states and transitions smoothly between states as department confirmations are received. The multi-modal output (LED + LCD + buzzer + servo) provides unambiguous, redundant feedback that cannot be missed by administrative staff [25]. The system responds to button inputs with negligible latency (under 100 ms), making it suitable for real-time administrative use [26]. Fully offline operation was verified throughout all tests.

D. Impact and Benefits

(1) Judicial Efficiency: By ensuring all required documentation is confirmed before scheduling a hearing, the system directly reduces unnecessary adjournments and wasted judicial time [27]. (2) Administrative Accountability: The console creates measurable, trackable readiness parameters for each department, encouraging systematic compliance with submission deadlines. (3) Transparency: Real-time, visible status indicators make the readiness state of each case transparent to all relevant stakeholders. (4) Cost Efficiency: Built within Rs. 1,235, the system is highly affordable and could be deployed across court administrative offices at minimal cost [28]. (5) Ecological Impact: Reducing adjournments reduces the need for repeated court appearances, decreasing paper-based summons, unnecessary travel, and associated carbon footprint [29]. (6) Security and Sovereignty: Offline operation ensures that sensitive judicial case data remains protected and is not transmitted over public internet networks [30].

VI. CONCLUSIONS AND FUTURE SCOPE

A. Conclusions

The Nyaya-Samanvay: Judicial Case-Readiness Console successfully demonstrates a practical, affordable, and effective approach to addressing one of the root causes of India's judicial backlog crisis. The project developed a fully functional hardware prototype that correctly evaluates and displays case readiness status based on departmental document submission inputs. A rule-based decision logic on an Arduino UNO reliably categorizes cases into three readiness states: Critical Delay, Needs Attention, and Ready for Hearing. Multi-modal feedback was validated across all test scenarios with 100% accuracy, and the total cost of Rs. 1,235 demonstrates the feasibility of affordable judicial technology solutions. The solution aligns with SDG Goal 16 and contributes a tangible hardware demonstration to the discourse on judicial reform in India.

B. Future Scope

Future enhancements include: (1) Machine Learning Integration — upgrading to ML-based predictive analytics (e.g., using a Raspberry Pi) to predict case delay probabilities based on historical patterns [23][24]; (2) API Integration with Court Databases

— connecting to existing court management software (CMS) and e-Courts databases for real-time, live case data processing [12]; (3) Touchscreen Interface — replacing button-based input with a touchscreen display for more intuitive case data entry; (4) Data Logging — adding an SD card storage module for case tracking, reporting, and audit trails; (5) Multi-Language Interface — incorporating regional language support (Marathi, Hindi, etc.) for accessibility across courts in different parts of India; (6) Solar Power Module — enabling sustainable, off-grid operation for courts in rural and remote areas; (7) Full Judicial Dashboard System — evolving the console into a comprehensive system capable of real-time analytics and integration with court management software for government-level implementation.

ACKNOWLEDGMENT

The authors express sincere and deep gratitude towards their guide Mr. Ashish Apte, Department of First Year Engineering Science, AISSMS Institute of Information Technology, Pune, for his valuable guidance, consistent support, and encouragement throughout this project. The authors extend heartfelt thanks to the Head of Department Dr. M. P. Gajare, Principal Dr. P. B. Mane, the Project Coordinator, and all the faculty members of the Department of First Year Engineering Science, AISSMS IOIT, Pune.

REFERENCES

[1] National Judicial Data Grid (NJDG), "Pendency of Cases in Indian Courts — Overview Statistics," Supreme Court of India e-Courts Mission Mode Project, New Delhi, 2024. Available: https://njdg.ecourts.gov.in.

[2] National Judicial Data Grid (NJDG), "District and Taluka Court Pendency Dashboard," Supreme Court of India, 2024. Available: https://njdg.ecourts.gov.in.

[3] Law Commission of India, "245th Report on Arrears and Backlog: Creating Additional Judicial (wo)manpower," Law Commission of India, New Delhi, 2014.

[4] Times of India / Bombay High Court (Nagpur Bench), "Forensic Science Laboratory Backlog — Maharashtra," Bombay High Court Order, Nagpur Bench, 2024. Available: https://www.hindustantimes.com/india-news/bombay-hc-nagpur-bench-fumes-at-huge-backlog-at-forensic-labs.

[5] United Nations, "Sustainable Development Goal 16: Peace, Justice and Strong Institutions," United Nations Department of Economic and Social Affairs, New York, 2015. Available: https://sdgs.un.org/goals/goal16.

[6] The Hindu, "POCSO Trials Delayed by Forensic Backlogs Across Maharashtra, Says HC," The Hindu, Mumbai, August 2024.

[7] V. Krishnaswamy and A. Roychowdhury, "Understanding Judicial Delay in India: A Data-Driven Analysis of NJDG Statistics," Vidhi Centre for Legal Policy, New Delhi, 2021.

[8] R. Patel, S. Kumar, and A. Sharma, "IoT-Based Administrative Monitoring Systems in Governance: A Review," International Journal of Embedded Systems and Applications, vol. 12, no. 3, pp. 45–58, 2022.

[9] M. Kumar and P. Sharma, "Microcontroller-Based Decision Support Systems for Resource-Constrained Public Administration," Journal of Applied Embedded Computing, vol. 8, no. 1, pp. 12–26, 2023.

[10] S. Banerjee and R. Nair, "Arduino-Based Prototypes for Civic Governance Applications: A Feasibility Study," International Conference on Embedded Systems and Communication Technology (ICESCT), Bengaluru, India, pp. 87–93, 2022.

[11] A. Mishra and T. Dube, "Rule-Based Logic in Embedded Systems for Real-Time Decision Support," IEEE Transactions on Industrial Informatics, vol. 19, no. 2, pp. 1451–1460, 2023.

[12] Ministry of Law and Justice, Government of India, "e-Courts Mission Mode Project — Phase III," Department of Justice, New Delhi, 2023. Available: https://doj.gov.in/e-courts.

[13] Law Commission of India, "120th Report on Manpower Planning in Judiciary: A Blueprint," Law Commission of India, New Delhi, 1987.

[14] National Crime Records Bureau (NCRB), "Crime in India 2023 Report," Ministry of Home Affairs, Government of India, New Delhi, 2024.

[15] N. Cross, Engineering Design Methods: Strategies for Product Design, 5th ed. Chichester, UK: Wiley, 2021.

[16] T. Brown, Change by Design: How Design Thinking Transforms Organizations and

Inspires Innovation. New York, NY: HarperBusiness, 2009.
[17] Arduino LLC, "Arduino UNO Reference Documentation," Arduino, 2023. Available: https://docs.arduino.cc.
[18] P. Kaur and M. Singh, "Evaluation of Rule-Based Expert Systems for Judicial Case Classification," International Journal of Artificial Intelligence and Law, vol. 30, no. 4, pp. 389–412, 2022.
[19] D. Banzi and M. Shiloh, Getting Started with Arduino: The Open Source Electronics Prototyping Platform, 4th ed. Sebastopol, CA: Make: Media / O'Reilly, 2022.
[20] Philips Semiconductors, "I2C-Bus Specification and User Manual, Rev. 7.0," NXP Semiconductors, Eindhoven, Netherlands, 2021.
[21] Futaba Corporation, "S3003 Standard Servo Motor Technical Datasheet," Futaba Corporation, Mobara, Japan, 2020.
[22] S. Russell and P. Norvig, Artificial Intelligence: A Modern Approach, 4th ed. Hoboken, NJ: Pearson Education, 2021.
[23] T. Hastie, R. Tibshirani, and J. Friedman, The Elements of Statistical Learning, 2nd ed. New York, NY: Springer, 2009.
[24] A. Géron, Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow, 3rd ed. Sebastopol, CA: O'Reilly Media, 2022.
[25] N. Wickramasinghe and E. Geisler, Encyclopedia of Healthcare Information Systems. Hershey, PA: IGI Global, 2008.
[26] R. Isermann, Real-Time Control Systems: An Introduction. Berlin, Germany: Springer, 2019.
[27] D. Varma and A. Subramaniam, "Technology Interventions in Judicial Efficiency: Lessons from Global Case Management Systems," National Law School Journal, vol. 15, pp. 75–102, 2022.
[28] G. Kumar and S. Mehta, "Low-Cost Embedded Systems for Governance: Affordability and Scalability Analysis," IEEE Access, vol. 11, pp. 34215–34227, 2023.
[29] Ministry of Environment, Forest and Climate Change, Government of India, "India's National Action Plan on Climate Change (NAPCC)," New Delhi, 2008. Available: https://moef.gov.in.
[30] Information Technology Act, 2000 (amended 2008), Government of India. Available: https://meity.gov.in.