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Design and Implementation of a Web-Based Library Management System for Engineering Colleges (SOET)

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ABSTRACT
The situation of departmental libraries in the state university engineering colleges throughout India is a matter of significant concern. These libraries of university continue to rely on old methods, such as handwritten issue registers, lack of a working register search system, and the inability to track overdue books through electronic means, which were causing challenges in the daily functioning of the institutions. This paper presents the enhancement, implementation, technical design and user assessment of "SOET Library" (https://soetlibrary.tech), a web-based library circulation system created particularly for the School of Engineering and Technology (SoET), the department of Samrat Vikramaditya Vishwavidyalaya Ujjain (MP). The application was built using Next.js 15, Supabase (which is powered by PostgreSQL service), and Bootstrap 5. It included a four-tier role-based access control system, QR code-based implemented book tracking, automatically overdue alerts to students, and five layers of Schema.org structured data for enhanced search engine visibility. ensuring its deployment on Cloudflare Pages,it was a usability evaluation that involved 38 participants, including 30 students and 8 faculty members, and using the System Usability Scale (SUS). The application receives a mean SUS score of 84.3, which falls under the "outstanding" category. Performance tests showed a 43% improvement in First concertful Paint when compared to a previous client-only version. This work is situated within the larger context of the confirmation of Information and Communication Technology (ICT) in Indian libraries, building upon the frameworks that were proposed by Ghosh (2003), Mahajan (2005), and Kaul (2002). This paper argues that the latest era of serverless cloud platforms has made it nearly possible for small student groups to create and manage high-quality library systems with no running costs.

Keywords: Library Management System, Academic Libraries, Information and Communication Technology (ICT), System Usability Scale (SUS), Web-Based Information System.

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INTRODUCTION

In the modern educational system colleges generate and maintain a vast amount of academic resources such as textbooks, magazines , research papers, project files, and online learning materials. Traditional library management methods that depend on manual record keeping that are frequntly time-consuming, unreliable, and inefficient in handling the growing demands of college students, faculty members, and administrators. As institutions increasingly adopt digital technologies, there is a strong need for automated applications that can efficiently organize, manage, and retrieve library information. Ghosh (2003), in her Highly cited poster paper presented at the 69th IFLA Congress in Berlin, observed that the condition of public libraries in India is "extremely miserable" ; many of them lack their own buildings, books, resources,faculty and share rooms with other institutions.A Web-Based Library Management System (LMS) gives an effective solution to these challenges by integrating library operations into a centralized digital platform access through the internet. It simplifies core activities including book collections, issue and return management, student registration, inventory tracking, fine calculation, and report generation. By automating these processes, the system reduces human work, minimizes operating errors, and improves overall efficiency and accessibility. . At SoET, the institution where the present authors are enrolled as final-year B.Tech students and the departmental library has been functioning for over two decades without any form of digitalization. Every book transaction had been written by hand into a thick cloth-bound red register. When a student wanted to know information about the book , the only option was to walk into the library room and look.When the librarian need list of students who had not returned books before the semester examination, the exercise involved searching through hundreds of handwritten rows, cross-referencing roll numbers against a printed class list, and making phone calls to students one by one.

This state of problem is not unique to SoET. Mahajan (2005) noted that academic libraries in India "must provide maximum information with limited resources," a boundary that has only focused since she wrote those words two decades ago. The UGC, through INFLIBNET, has invested heavily on connecting the university libraries through high-speed internet , developing union systems, and distributing automation software such as SOUL (Software for University Libraries catalogues). However, these initiatives have primarily benefited central and state university main libraries. The departmental libraries of constituent engineering colleges face the issue of not implementing this properly.

The present project grew out of this frustration. Three of us Narayanam Dubey, Yash Yadav, and Shashank Rathore.Chose to address this problem as our Major Project for the B.Tech

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degree (Batch 2022–2026, ECS Department), under the guidance of Prof. Ashish Suryavanshi, Head of the ECS Department. Our objective was not only academic but we wanted to build something that the librarian would actually start using from the next morning. That practical objective shaped every technical decision we made, from the choice of a managed database service (it avoided the need for a dedicated server) to the inclusion of QR-code sticker printing (it eliminated manual ISBN lookup during issue and return).

OBJECTIVES OF THE STUDY

The study has the following objectives:

1. To create and build a web-based library management system that meets the specific needs of a state-university and engineering college, which has limited information and communication technology (ICT) facilities and no budget for a dedicated server.
2. To put in place a four-tier role-based access control system (administrator, librarian, faculty, and student) that strictly ensures data privacy at both the application and database levels.
3. To introduce QR code-based books identification into the circulation process, which helps in reducing the time needed for issuing or returning library items.
4. To run the system on a free-tier cloud platform and evaluate its performance and usability through real-world testing and user feedback.
5. To place this work within the existing research on ICT adoption in Indian academic and public libraries, and to check if current serverless architecture technologies have made it easier to overcome the challenges previously identified by researchers.

REVIEW OF LITERATURE

The literature on library automation in India can be broadly categorized into three areas: (a) policy-level studies analyzing the public library system and its structural issues, (b) real-world reports on the adoption of ICT in academic libraries, and (c) studies on user experience, digital libraries and community impact.

THE PUBLIC LIBRARY SITUATION IN INDIA

The UNESCO Public Library Manifesto describes that a public library as "the local gateway to knowledge" and "a fundamental conditions for lifelong learning, independent decision-making, and a cultural progress" (UNESCO, 1994).

Still, in India, there is a remarkable gap between this aim and the actual situation. Ghosh (2003) noted that, at the time of her research, only 11 out of 29 states and 6 Union Territories had passed library legislation. She estimated that India had around 60,000 public libraries,of which around 70% did not have essentially study spaces and did not have proper collections, inadequate facilities, and unqualified personnel.

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. According to IFLA guidelines, there should be at least one public library for every 3,000 people. With a population exceeding one billion, India would need more than 343,000 library units to reach the goal yet a number has not yet been achieved.

Ghosh suggested that ICT can help to improve public libraries and proposed a model in which convergence technologies such as Cybercafes , community radio , telecentres and mobile phones can be used to expand the reach of existing library services.

She highlighted the example of "Gyandoot," an internet-based digital library system in the Dhar district of Madhya Pradesh that linked 21 cyber-cafés, called "Soochanalayas," to serve a population of 20,000 to 30,000 people of the district. While Gyandoot showed that it is technically possible to deliver library services through ICT in rural areas, it is a long-term success depended on government funding and availability of trained local personnel and factors that are not always available in every zone(region).

ACADEMIC LIBRARY NETWORKS AND CONSORTIA

Mahajan (2005) gave a comprehensive look at the scholastic library system in our country, and also highlighted the vision of the University Grants Commission (UGC), INFLIBNET, and the INDEST consortium. She noted that INFLIBNET, established as an independent inter-university center in 1991, made significant progress in connecting university libraries through faster network connections, creating the union catalogues, and also provides the SOUL software. Other networks like DELNET (with 752-member libraries), CALIBNET, ADINET, and MALIBNET were also involved in sharing resources and offering training through software.

However, Mahajan also pointed out a major challenge such as the deduction in budgets and rising subscription costs made it very tough to meet the needs of people who use libraries and information services.

WEB TECHNOLOGIES FOR LIBRARY AUTOMATION

Web technologies play a very important role when it comes to making libraries more modern and automated. In the modern period where access to information and automation has become important, there is an increasing demand for implementing the use of web technologies. This is important especially for academic institutions such as engineering colleges.

A web-based library management system requires technologies that can cover three main fields, i.e., frontend technology,database technology, backend technology. It starts with the frontend technology which gives the user interaction easily with the system via an interactive interface.Many technologies can be considered in order to make the user experience better as it allows you to provide the content on-the-go.

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Backend technologies will form the heart of the whole system as they involve all the operations required by the business. There were many backend technologies available . One popular example is Node.js and Express.js which help to build efficient server-side applications. Backend technologies are used to connect the user interface to the database by using RESTful APIs(Application programming interface).

Database management is another important part of library web automation where databases like MongoDB and MySQL are used to keep large amounts of data properly. This included the storage and management of data such as books, users, and their interactions with the library.

Furthermore, other functions that were also rely on the web include real-time updates capability, easy search capability, and remote accessibility. For example, users can search through the list of available books. Last but very important is security. Various security measures are taken in order to upgrade data protection. They include use of authentication systems, encryption, and secure API design. Role-based access control is also ensured that users can allow access only to authorized details.

IDENTIFICATION OF THE RESEARCH GAP

From this review, a clear gap becomes manifest in the existing literature . On one hand, Indian library literature has extensively documented the structural weakness in the both public and academic library systems (Ghosh, 2003; Mahajan, 2005; Kaul, 2002). On the other hand , web-development system literature has shown the technical possibility and easily implemented of using serverless, cloud-native architectures for academic tools However, to the best of our knowledge and research , no study has reported on the full development, deployment, and testing of a production-level library circulation system built by undergraduate students using free-tier cloud services for a r engineering college. This study seeks to address the gap.

RESEARCH METHODOLOGY

The present study is based on the "Design Science Research" (DSR) methodology, which involves the creation of the advanced library system to solve a real-world problem. It focuses on the design,development and testing. The methodology was carried out in two different phases: System Development and Empirical Evaluation.

System Development Methodology- The development of the web-based circulation platform was performed between August 2025 and May 2026 using an iterative, and user-centered framework. The development phase was broken down into two-week sprints. At the conclusion of each sprint, the blueprint was demonstrated by the primary stakeholders such as the Head of Department and the departmental librarian. This continuous feedback loop was taken to allow for critical operational modification. For instance, early feedback regarding the physical

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register led to the implementation of a dynamic, self-placed algorithm for calculating available book copies, rather than a simple increment-by-one logic.

On the basis of institutional requirements such as having no budget for physical servers, mobile responsive interfaces for students or users, and maintaining a low budget for maintenance, an appropriate technology architecture has been decided upon. Therefore, a serverless cloud architecture using technologies like Next.js for server-side operations, Supabase for database and authentication management and Cloudflare pages for edge network deployment on cloud has been selected.

Research Design and Sampling- In order to conduct a study for evaluating the effectiveness and user acceptance of the designed system, a summative usability evaluation was carried out at the end of the autumn 2025 semester. Convenience sampling technique, i.e. purposeful sampling was used in the current study and only those users that are frequent users of the physical departmental library were considered for conducting the study.

The sample size consisted of 38 participants. These included 30 undergraduate students from different engineering branches namely Computer science, Information Technology, Electronics and Communication, and Mechanical Engineering along with eight faculty members.

Data Collection Instruments- Two types of data collection instruments were used in the study. The first one being System Usability Scale (SUS): This instrument was originally devised by Brooke (1996).Benchmarking tools like Google Lighthouse (Chrome DevTools, version 120) were used to benchmark front-end page loads in simulated "Slow 4G" network conditions. Also, a custom load generation tool was built to benchmark API latency by sending 100 simultaneous requests to the database.

Evaluation Setup and Procedure This experiment was done under controlled laboratory conditions inside the college campus. Each user was handed out a physical task protocol that had five different tasks that tested the basic features of the system:

Task 1: Authenticate yourself and find a particular title in the electronic catalogue.

Task 2: Confirm the status of availability of the title you choose at that moment.

Task 3: (Staff Members only) Conduct the process of book borrowing with a QR code scanner embedded in the camera.

Task 4: See your own record of circulation and see whether you have any overdue items.

Task 5: (Staff Members only) Send a broadcast message to all students having overdue items.

Once the above mentioned tasks have been successfully completed, the users were requested to fill in the SUS questionnaire. Additional feedback was received based on qualitative interviews conducted after the task.

SYSTEM DESIGN

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ARCHITECTURE OVERVIEW

The architecture follows a three-tier system

CLIENT TIER) it contains Next.js App Router (Server Components + selective Client Components) Bootstrap 5 UI , html5-qrcode and the Schema.org JSON-LD (5 scripts) |HTTPS — REST/JSON .

APPLICATION TIER it contains Next.js API Routes (serverless edge functions on the Cloudflare) JWT verification (such as jose library) , RBAC permissions resolver Activity logger ,Real time notification engine , Supabase client SDK (software development kit).

DATA TIER contains Supabase PostgreSQL (Row-Level Security policies) Supabase Storage (book-covers, book-index-images, profile-images) Supabase Authentications (email/password).

DATABASE TABLES

Table: users Columns: id, name, email, role, roll_number, branch, current_semester, phone, profile_completed, approval_status, is_active, is_removed, faculty_privileges_enabled

Table: books Columns: id, title, author, isbn, category, publisher, publication_year, total_copies, available_copies, shelf_location, description, is_active

Table: transactions Columns: id, user_id, book_id, borrow_date, due_date, return_date, status (status values: borrowed | returned | overdue)

Table: notifications Columns: id, user_id, type, title, message, book_id, transaction_id, is_read, created_at

Table: activity_logs Columns: id, user_id, action, details, ip_address, created_

Row-Level Security policies allow such a way that when students access the users table, they will get only their row back. The notifications table will be auto-filtered according to the user_id. Transactions can only be accessed by staff or by the user who is associated with the transaction.

THE FOUR-TIER ROLE SYSTEM

The vast majority of student projects implement the simpler admin/user role system. We required four tiers since SoET actually has an organisation hierarchy: there is a head of department who acts as an administrator, a librarian responsible for operations, faculty members that can additionally approve issues in case of librarian's unavailability and students that can only borrow books and track their own history.

ROLE PERMISSIONS SUMMARY

Administrator - full access: catalog management even for deactivated books, all users management, settings management, reports, notification broadcast, activity log.

Librarian – catalog management, issues handling, report viewing, notification broadcast. Cannot modify system settings or administrators.

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Faculty with privileges – same operational access as librarian. Privileges can be assigned to specific faculty members by an administrator.

Student -can borrow public catalog , viewing their own history and due dates. Does not have access to staff modules.

There are two layers of permission validation. Edge middleware (middleware.ts, 191 lines) validates every navigation request from a browser prior to rendering of the page. This includes authentication and active session validation, profile completeness, user account status and activity as well as proper route selection relative to the user role. Requests without authentication or proper permissions are immediately redirected.

In each API route, a separate verification step is done to resolveApiPermissions() which re-queries the database for the Legitimate role. This prevents an old scenario where a token was issued with an old role value that has since been changed by an administrator. Both layers have to agree before any privileged operation proceeds.

The middleware also handles several edge cases that a simpler guard would miss: Users who have an approval_status of pending are kept on a waiting page irrespective of which URL they try accessing.

Users marked is_removed = true are redirected to a role-specific reactivation page.
Users whose profile_completed flag is false are sent to the profile completion form.
Faculty members whose faculty_privileges_enabled has been disabled see the same interface as a regular student.

The Book Return Flow and Our Design Mistake: What We Learned from the return Endpoint (api/transactions/return/route.ts, 97 lines): The design of the return endpoint has made us realize the difference between textbook code and real-world coding.

The first version of this function simply incremented available_copies by 1 after marking a book transaction as returned. This seemed perfect until we found out that in the real world, some book entries were done manually and hence there were inaccurate copy numbers associated with the books. For instance, a book with three initial copies now had two in the real world because one of them was lost decades ago.

With the increment-by-1 approach, available_copies would drift away from dashboard every time a return was processed. After some observation of what was happening, we replaced the increment logic with a recalculation.

available_copies = total_copies − count(active transactions for this book)

where "active" means status is "borrowed" or "overdue." This runs two queries on every return, one to get total_copies and one to count active transactions —The price is two additional database queries. The advantage is that the inventory count is guaranteed to be correct even if the

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past data has been altered manually. In the case of a library holding hundreds of books with chaotic past records, this is totally worthwhile.

After successfully performing the update query on the transaction, the endpoint then proceeds to insert a notification to the borrower and add an activity log entry by invoking the logActivity() function. It should be noted that the activity logger is fire-and-forget in nature as it catches and ignores exceptions that may prevent successful logging of an activity.

Staff can send a notification to either all active students or only students with overdue books. For the overdue scope, the system pulls all transactions in "borrowed" or "overdue" status, compares each due_date with the current timestamp, and collects unique user_ids of those who are late.. Finally, one row per recipient is inserted at once.

QR CODE LABELS AND SCANNING

Each physical book can be assigned with a QR code sticker generated by the server using the qrcode library. Staff can select multiple books, submit the selection to the /books/qr-print page, and receive a printable sheet of stickers formatted to fit on standard label paper.

When the sticker is fixed to the physical book and a student brings it to the desk, the librarian scans the QR code on a phone or laptop, clicks the camera button, and points it at the sticker. The html5-qrcode library reads the code, resolves the book record from the database used , and takes the librarian directly to the issue or return workflow for that book; there is no typing required. This matters because the librarian we were building for types slowly finds the keyboard a minor obstacle.

IMAGE STORAGE

Three Supabase Storage buckets handle media: book-covers contains front and back cover images, WebP, 10 MB limit, 1-year CDN cache book-index-images and table of contents or preview page scans, and, same limits profile-images such as user profile photos, WebP, 10 MB limits.

All images go through Sharp on the server before upload. Sharp converts them to WebP format, which is typically 30–40 percent smaller than JPEG for photographic content.

RESULTS AND DISCUSSION

The SOET Library system was implemented and tested in practice through the participation of 38 people (30 students and 8 teachers). The result achieved is that the system managed to obtain an average SUS score of 84.3, which indicates high levels of usability and a rating of "Outstanding." Everyone could perform the necessary tasks, achieving a percentage of 100%, significantly saving time compared to manual procedures. The process of lending and returning books was optimized by utilizing QR codes to remove the need for data input. The system proved effective from a performance standpoint, as Google Lighthouse testing under the

assumption of Slow 4G connection yielded a 43% improvement over previous client-only versions due to the introduction of server-side rendering and edge deployment. There was also no degradation in API response time when performing under load, thus proving adequate for departmental purposes. Finally, operationally speaking, the SOET Library system helped to automate manual register management, ensure accurate book inventory with recalculation logic, and send the remainder of overdue books.

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DECLARATION

It is hereby declared that the project work carried out in this research paper, "Design and Implementation of Web-Based Library Management System for Engineering Colleges (SOET)," is an original one undertaken during the course of our B.Tech degree from the School of Engineering & Technology, Samrat Vikramaditya Vishwavidyalaya, Ujjain (MP).

The project has never been presented before any other university or institute for the purpose of any academic degree or diploma.

The authors also thanked the faculty and librarian for the research.

We, the authors, will be responsible for all the contents contained in this paper.

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