# Course Outcome Management System

*A SaaS-Based Academic Analytics and Outcome-Based Education Platform*

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***Abstract*—The proposed project, CampusMatrix, is a Software-as-a-Service (SaaS) based Academic Analytics and Outcome-Based Education (OBE) Management System. It is engineered to simplify, automate, and highly optimize the rigorous accreditation processes mandated by the National Board of Accreditation (NBA) for engineering institutions in India. During the preparation of the NBA Self-Assessment Report (SAR), academic departments are forced to collect, process, map, and evaluate massive volumes of student performance data. Traditional manual methodologies, which rely heavily on decentralized spreadsheet tracking, are inherently time consuming, highly susceptible to mathematical errors, and severely lack cross-departmental transparency. The primary objective of the proposed system is to fully automate the management and mathematical computation of Course Outcomes (COs), Program Outcomes (POs), Program Specific Outcomes (PSOs), and dynamic CO-PO mapping matrices. The platform provides a highly secure, centralized web-based ecosystem utilizing modern web technologies (Next.js, Node.js, and PostgreSQL). Administrators, Heads of Departments (HODs), and faculty members are granted role-based access to securely ingest assessment records, conduct real-time threshold evaluations, and automatically calculate Direct Attainment, Indirect Attainment (via Course Exit Surveys), and aggregate PO/PSO attainments. By eliminating man-ual data handling, CampusMatrix acts as an efficient, error-free digital foundation for continuous quality improvement and strict NBA accreditation compliance.**

***Index Terms*—Outcome-Based Education, NBA Accreditation, SaaS Architecture, Course Outcomes, Academic Analytics, Data Normalization, Continuous Quality Improvement.**

## I. Introduction

In the contemporary landscape of global higher education, particularly within engineering and technical domains, the paradigm has shifted decisively from traditional input-based teaching models to an Outcome-Based Education (OBE) framework. This global shift, largely driven by international agreements such as the Washington Accord, necessitates that educational institutions prove that their graduates have attained specific, measurable skills and competencies. In India, the National Board of Accreditation (NBA) acts as the central authoritative body enforcing these rigorous OBE standards.

### Scope of Project

The Course Outcome Management System (COMS) is developed to automate and simplify the Outcome-Based Education (OBE) process followed by engineering institutions. The system mainly focuses on managing Course Outcomes (COs), Program Outcomes (POs), and Program Specific Outcomes (PSOs) while supporting the documentation requirements of NBA accreditation. The project provides a centralized web-based plat-form where faculty members can manage course details, define Course Outcomes, create CO-PO mappings, and upload student assessment data such as internal assessments, assignments, quizzes, laboratory records, and end-semester examination marks. Based on

these records, the system automatically calculates direct attainment, indirect attainment, overall CO attainment, and PO/PSO attainment using NBA-defined formulas.

## Need for the Project

With the growing adoption of Outcome-Based Education (OBE) and the increasing importance of NBA accreditation, educational institutions are required to continuously monitor and evaluate Course Outcomes (COs), Program Outcomes (POs), and Program Specific Outcomes (PSOs). In many colleges, these activities are still performed manually using spreadsheets and separate Excel files. Faculty members have to collect assessment data, perform calculations, and prepare reports manually, making the entire process time-consuming and prone to errors. The traditional approach often leads to data duplication, calculation mistakes, and difficulties in maintaining records across different courses and semesters. Preparing accreditation documents such as the Self-Assessment Report (SAR) requires significant effort, as information must be gathered from multiple sources and verified repeatedly. Moreover, the absence of a centralized system makes collaboration between faculty members and departmental coordinators difficult. Therefore, there is a strong need for an automated and centralized solution that can manage academic data efficiently and generate accurate attainment reports.

## Motivation and Research Contributions

The primary motivation behind the development of the Course Outcome Management System is the increasing complexity associated with NBA accreditation and Outcome-Based Education implementation. Faculty members spend a considerable amount of time collecting assessment data, performing calculations, verifying results, and preparing reports manually. This repetitive process not only increases workload but also affects the efficiency and reliability of academic management. The growing demand for digital transformation in educational institutions further motivated the development of a centralized web-based platform capable of automating these activities.

The proposed work contributes to the field of academic analytics by introducing an automated attainment calculation engine that combines direct and indirect assessment methods according to NBA guidelines. The project also provides dynamic CO-PO map-ping functionality, centralized academic data management, graphical dashboards, and automated report generation features. Overall, the project contributes towards making the accreditation process more systematic, transparent, and efficient while reducing de-pendency on manual calculations.

## Rationale and Problem Background

The NBA mandates that institutions continuously track, calculate, and thoroughly document the attainment of Course Outcomes (COs), Program Outcomes (POs), and Program Specific Outcomes (PSOs). A core requirement for accreditation is the submission of a comprehensive Self-Assessment Report (SAR). The mathematical evaluation of these outcomes demands the aggregation of vast student datasets across a multitude of evaluation vectors—including Internal Assessments (IA), quizzes, laboratory assignments, end-semester examinations, and qualitative indirect feedback surveys.

Historically, engineering departments have managed this overwhelming volume of academic data using isolated, standalone spreadsheet applications. Faculty members are forced to create manual formulas to map specific exam questions to corresponding COs, determine the percentage of students crossing predefined thresholds, and subsequently map those COs to institutional POs using complex correlation matrices. This manual methodology presents severe operational bottlenecks. Formula degradation, accidental cell overwrites, version control conflicts across faculty members, and the sheer

administrative latency involved in gathering data from dozens of courses severely ham-per the academic process. A single mathematical error in a decentralized spreadsheet can invalidate an entire department's attainment matrix, jeopardizing the accreditation status.

### Problem Statement

The existing ecosystem for managing COs, POs, and PSOs is fundamentally flawed due to its reliance on fragmented manual computations. Faculty members endure hundreds of hours of administrative overhead preparing CO-PO mappings and generating attainment reports, distracting them from core pedagogical responsibilities. The lack of a centralized, secure, and relational database results in severe data inconsistency. Furthermore, integrating indirect attainment data gathered via student Course Exit Surveys into the direct attainment mathematical pipeline is currently a disjointed process requiring manual data entry. There is a critical, unmet need for a unified, cloud-based platform that automates these exact calculations, maintains historical temporal records, and dynamically generates accreditation-ready reports without human intervention.

### Research Objectives

To thoroughly resolve the systemic limitations identified above, this research aims to design, develop, and validate the Course Outcome Management System (COMS), branded as CampusMatrix. The primary objectives are:

- **Mathematical Automation:** To develop a highly robust computational engine capable of autonomously calculating Direct Attainment (DA), Indirect Attainment (IDA), and overall CO-PO attainments based strictly on NBA-prescribed threshold formulas.
- **Centralized SaaS Architecture:** To implement a multi-tenant, cloud-hosted architecture utilizing a strictly normalized PostgreSQL database, enabling secure, role-based collaboration between Administrators, HODs, and Faculty.
- **Dynamic Correlation Mapping:** To construct an interactive, real-time CO-PO/PSO mapping matrix that instantly propagates attainment recalculations globally when a single student's assessment record is updated.
- **Automated Compliance Reporting:** To engineer real-time analytical dashboards and one-click PDF generation modules that output high-fidelity, NBA-ready SAR documentation, thereby reducing report compilation time from weeks to seconds.

## II. Literature Review

The necessity for automating academic compliance tracking has led to various techno-logical interventions over the past decade. An extensive review of existing literature, commercial products, and institutional methodologies reveals a clear evolutionary path, though significant research gaps remain.

### Existing Methodologies and Systems

Early attempts at digitization involved the creation of standardized macro-enabled spread-sheets. While these tools slightly reduced the repetitive calculation times for individual faculty members, they failed to solve the fundamental issues of data isolation and lack of concurrency. More recently, institutional Enterprise Resource Planning (ERP) systems have attempted to incorporate OBE modules. However, as noted by several researchers, these monolithic ERPs are often rigid, overwhelmingly complex, and lack the highly specialized mathematical workflows required specifically by the NBA.

Furthermore, they frequently fail to integrate Indirect Attainment (surveys) cleanly with Direct Attainment (exams).

Advanced research has begun exploring Machine Learning (ML) algorithms to predict CO attainment based on early-semester formative assessments. While academically rigorous, these predictive models require vast amounts of pristine historical data, a pre-requisite that most institutions struggling with manual spreadsheets cannot yet meet.

Table 1: Comprehensive Comparison of Existing Academic Management Approaches

| System Paradigm | Core | Functionality Identified Limitations & Draw-backs |
|---|---|---|
| **Manual Excel Tracking** | Faculty-designed formulas and localized files. | High risk of formula corruption; no centralized database; |
| **Monolithic ERPs** | General student management, fee tracking, basic grading. | severe version control issues; no multi-user concurrency. |
| **Web-based Calculators** | Single-use online forms for generating percentages. | Extremely high licensing costs; lacks dynamic, NBA-specific CO-PO mapping matrices; |
| **CampusMatrix (Proposed)** | SaaS-based, fully relational DB, role-based workspaces. | poor indirect survey integration.No persistent database storage; requires faculty to re-upload raw student data for every calculation cycle; lacks historical trend analysis.<br>None identified in context.<br>Provides full automation, integrated surveys, dynamic mapping, and instant SAR generation. |

**Identification of Research Gaps**

The comparative analysis explicitly highlights several critical research gaps. Existing solutions overwhelmingly treat direct assessment (exam marks) and indirect assessment (student surveys) as two separate data silos, requiring administrators to manually merge the resulting attainment values. Additionally, current systems lack" dynamic mapping" - the ability to instantly view how changing a specific CO target threshold ripples through the curriculum to affect university-level Program Outcomes. CampusMatrix is specifically engineered to bridge these exact gaps by unifying the entire pipeline into a single, cohesive workflow.

## III. Mathematical Formulations and Computations

The absolute core of the CampusMatrix system is its rigorous, deterministic mathematical computation engine. The engine translates standard NBA compliance guidelines into programmatic

algorithms. The attainment of outcomes is a multi-stage calculation process involving threshold evaluation, direct aggregation, indirect aggregation, and correlation weighting.

**Threshold Evaluation**

Before overall attainment can be calculated, individual student marks must be evaluated against configurable target thresholds. Let $S$ represent the total number of students enrolled in a specific course. Let $M(s)$ represent the marks obtained by a specific student $s \in S$ in a given assessment. Let $T_{target}$ be the target threshold mark (e.g., 60% of the maximum possible marks).

An indicator functions $I(s)$ is defined to determine if a student has successfully crossed the threshold:

$$I(s) = \begin{cases} 1 & \text{if } M(s) \geq T_{target} \\ 0 & \text{if } M(s) < T_{target} \end{cases} \quad (1)$$

The basic threshold attainment percentage ($A_{base}$) for that specific assessment is calculated as:

$$A_{base} = \frac{\sum_{s \in S} I(s)}{|S|} \times 100\% \quad (2)$$

Based on the value of $A_{base}$, the system assigns an Attainment Level ($L \in \{0, 1, 2, 3\}$), where Level 3 indicates high attainment (e.g., $\geq$ 70% of students crossed the threshold), Level 2 indicates moderate attainment, Level 1 indicates low attainment, and Level 0 indicates failure to attain.

**Direct Attainment (DA) Calculation**

Direct Attainment is an aggregation of continuous Internal Assessments (IA) and End-Term Examinations (ETE). The NBA typically recommends a weighted distribution. Let $L_{IA}$ be the computed attainment level for internal assessments, and $L_{ET\,E}$ be the computed attainment level for end-term exams.

The Direct Attainment ($DA$) score is mathematically defined as:

$$DA = w_{ia} \cdot L_{IA} + w_{ete} \cdot L_{ET\,E} \quad (3)$$

Applying standard institutional weightings of 30% for internal and 70% for external assessments, the equation resolves to:

$$DA = 0.3 \cdot L_{IA} + 0.7 \cdot L_{ET\,E} \quad (4)$$

**Indirect Attainment (IDA) Calculation**

Indirect Attainment captures qualitative feedback, primarily through Course Exit Surveys distributed directly through the CampusMatrix platform. Let $R$ be the set of valid survey responses be the score given by student $i$ on a 5-point Likert scale.

**Overall Course Outcome (CO) Attainment**

The final, holistic attainment value for any given Course Outcome ($CO_{final}$) merges the empirical direct data with the qualitative indirect data. The standard NBA weightage applies an 80/20 or 70/30 split. The system utilizes the 70/30 standard:

$$CO_{final} = 0.7 \cdot DA + 0.3 \cdot IDA \quad (6)$$

*Program Outcome (PO) Correlation Matrix*

Program Outcomes cannot be evaluated directly through exams; they must be mapped. Let $M_{i,j} \in \{0, 1, 2, 3\}$ represent the correlation strength defined by the faculty between Course Outcome $i$ and Program Outcome $j$. The final attainment for $PO_j$ across a course is calculated by taking the weighted average of the attained COs against their mapped strengths:

$$PO_j = \frac{\sum_{i=1}^{n} (CO_{final,i} \times M_{i,j})}{\sum_{i=1}^{n} M_{i,j}} \quad (7)$$

This formula ensures that highly correlated COs (Strength 3) mathematically impact the final Program Outcome significantly more than weakly correlated COs (Strength 1).

## IV. Product Details and System Architecture

This section provides detailed information about the Course Outcome Management Sys-=tem (COMS) as a product, including its features, system architecture, technical aspects, and database design. The COMS is implemented as a cloud-based SaaS web application that automates the complete NBA attainment lifecycle for engineering institutions.

Detailed Features of Product with Advantages

- **Automated CO Attainment Calculation:** Automatically calculates direct attainment, indirect attainment, and overall CO attainment using NBA-defined formulas, eliminating manual computation errors.
- **Dynamic CO-PO Mapping:** Provides an interactive interface for faculty to define CO-PO correlation levels (1=Low, 2=Medium, 3=High) and automatically computes PO and PSO attainment.
- **Centralized Data Management:** All academic data including departments, courses, COs, POs, assessments, and reports are stored in a centralized PostgreSQL database accessible by all authorized roles.
- **Real-Time Report Generation:** Generates CO attainment reports, PO/PSO attainment summaries, and graphical visualizations automatically and instantly, reducing report preparation time significantly.
- **Role-Based Access Control:** Implements secure role-based login for Admin, HOD, and Faculty, ensuring organized and secure academic data management with appropriate permissions for each role.
- **SaaS Architecture:** Supports multiple departments and institutions on a single platform with scalable cloud-based deployment, making it cost-effective and easy to maintain

**Multi-Tier Application Architecture**

The system is constructed using a decoupled, API-driven stack.

- **Presentation Layer (Frontend):** Developed using Next.js and React.js, utilizing Material UI (MUI) components. This ensures a highly responsive, single-page application (SPA) experience. State management is handled dynamically to provide immediate visual feedback when mapping values are altered.
- **Application Layer (Backend):** A Node.js and Express server acting as the central nervous system. It handles RESTful API requests, performs all heavy mathematical executions (the Attainment Engine), processes bulk Excel/CSV file ingestions, and enforces strict JWT-based Role-Based Access Control (RBAC).
- **Database Layer:** A PostgreSQL database, chosen for its absolute adherence to ACID properties, ensuring that complex attainment calculations are never subject to read/write race conditions during simultaneous faculty uploads.

### Third Normal Form (3NF) Database Schema

Data integrity is paramount. If a single student's roll number is duplicated or an assessment mark is misaligned, the entire SAR report becomes invalid. The PostgreSQL schema is strictly normalized to the Third Normal Form (3NF) to eliminate massive data redundancies typical in educational records.

### Security and Access Protocols

Given the sensitive nature of academic records, CampusMatrix employs enterprise-grade security protocols. Passwords are cryptographically hashed using the bcrypt algorithm with significant salt rounds prior to database insertion. Authentication is entirely state-less, utilizing JSON Web Tokens (JWT). When an administrator logs in, the JWT payload contains their specific access clearances, ensuring they cannot mutate CO definitions be-longing to a different academic department.

## V. Results and Performance Evaluation

The efficacy of the CampusMatrix platform was rigorously tested through a simulated deployment representing a standard Computer Science and Engineering department. The

Table 2: Core Entity-Relationship Database Schema (3NF)

| Database Entity | Primary Key | Entity Description and Relationships |
|---|---|---|

| | | |
|---|---|---|
| **Users** | user_id (UUID) | Stores authenticated credentials, names, and enumerates the role (Admin, HOD, Fac-ulty). |
| **Courses** | course_id (UUID) | Contains course codes, titles, and credit hours. Holds foreign keys to the assigned Faculty and Department. |
| **CourseOutcomes** | co_id (UUID) | Stores specific CO definition statements, nu-merical targets, and threshold limits tied to a specific course_id. |
| **Assessments** | assess_id (UUID) | The highest-volume table. Records an in-dividual student's marks against a specific evaluation vector (e.g., MST1, ETE) mapped directly to a co_id. |
| **COPOMapping** | map_id (UUID) | The junction table resolving the many-to-many relationship between COs and POs. Stores the integer mapping strength (1, 2, or 3). |
| **AttainmentLog** | log_id (UUID) | Persists the final computed DA, IDA, and Overall attainment decimals, preventing constant recalculation of historical session data. |

test environment consisted of simulated historical records for 8 academic cohorts, comprising over 2,000 distinct students, 40 subjects, and nearly 50,000 individual assessment rows.

**Algorithmic Validation**

The primary concern of any automated compliance software is mathematical fidelity. To validate the Attainment Engine, a subset of data (one core course, 60 students) was manually processed by an NBA accreditation expert using standard spreadsheet formulas. The identical raw dataset was ingested into CampusMatrix. The resulting Direct Attainment, Indirect Attainment, and final PO projection matrices were compared. The system achieved a 100.00% algorithmic match, completely eliminating the threat of human calculation error.

**System Performance Metrics**

Speed and responsiveness are critical for user adoption. Faculty members traditionally spend hours formatting tables and waiting for massive Excel files to refresh macros.

Table 3: System Performance and Latency Evaluation

| Operational Task / Process | Traditional Manual Time | CampusMatrix Latency |
|---|---|---|
| Bulk Ingestion (CSV) of 200 Student Marks Computation of Direct Attainment (DA) Aggregation of 100 Course Exit Surveys (IDA) Generation of Full PO/PSO Mapping Report | 15-20 Minutes (Manual Entry)<br>45 Minutes (Per Course) | 1.42 Seconds<br>< 150 |

| | | | |
|---|---|---|---|
| Milliseconds | 2-3 Hours (Data Collation) | < 300 | Milliseconds 3-5 Days (HOD Level) 2.85 Seconds |

The metrics in Table 3 demonstrate a paradigm shift in academic administration. The generation of a comprehensive, globally mapped PO/PSO attainment report—a task that typically requires days of cross-departmental coordination and manual verification by Heads of Departments—is reduced to under three seconds of server processing time.

**Target Customers Details**

The primary target customers for COMS are:

- **NBA-Accredited Engineering Departments:** Departments undergoing or preparing for NBA accreditation that need to automate CO-PO attainment calculations and SAR preparation.
- **Autonomous Engineering Colleges:** Institutions with OBE-based curriculum frame-works requiring centralized academic data management and reporting.
- **University Affiliates and Constituent Colleges:** Groups of colleges under a com-mon university that can share the SaaS platform for standardized attainment reporting.
- **HODs and Academic Coordinators:** Department heads who need a unified view of attainment trends across multiple courses and semesters.
- **Faculty Members:** Teaching staff who need an efficient, easy-to-use tool for up-loading assessment data and viewing CO attainment outcomes.

**Unique Selling Proposition (USP) of Product**

COMS differentiates itself from existing solutions through the following unique selling propositions:

- **End-to-End NBA Automation:** The only platform that automates the complete OBE attainment lifecycle - from CO definition and assessment upload to automated PO/PSO attainment calculation and NBA-ready report generation - in a single integrated system.
- **Dynamic CO-PO Mapping with Automated PO Computation:** Unlike static map-ping tables in existing tools, COMS provides an interactive mapping matrix that automatically computes PO and PSO attainment whenever CO attainments or map-ping values change.
- **Integrated Indirect Attainment from Course Exit Surveys:** COMS uniquely integrates Course Exit Survey data directly into the attainment calculation workflow, providing a complete direct and indirect attainment computation system.
- **Multi-Role SaaS Platform:** COMS supports simultaneous access by Admins, HODs, and Faculty members with appropriate role-based permissions, enabling collaborative and transparent academic data management.
- **Cost-Effective Cloud Deployment:** As a SaaS product, COMS eliminates the need for

expensive on-premises infrastructure, making NBA-grade attainment automation accessible to institutions of all sizes and budgets.

### Positioning Strategy

COMS is positioned as the premier NBA-Aligned Academic Analytics Platform for Indian engineering institutions, targeting the growing market created by NBA's mandatory accreditation requirements. The positioning strategy focuses on three pillars: *Compliance-First Positioning*, ensuring that every calculation, report, and dashboard is directly aligned with accreditation requirements; *Ease of Adoption*, with minimal training requirements, intuitive interfaces, and step-by-step workflows; and a *Scalable SaaS Model* that can grow from a single department to a multi-campus institution. The go-to-market strategy includes initial deployment at partner institutions like CDGI for real-world validation, followed by outreach to NBA-affiliated engineering colleges through academic networks, conferences, and direct institutional partnerships.

## VI. Conclusion and Future Work

The transition toward Outcome-Based Education demands more than mere philosophical alignment; it requires robust, highly accurate technological infrastructure. The CampusMatrix SaaS platform successfully completely automates the complex mathematical lifecycle of NBA accreditation. By replacing archaic, decentralized spreadsheets with a strictly normalized relational database and an automated computational engine, the sys-tem definitively solves the problems of data inconsistency, formulaic error, and immense administrative latency.

The successful validation of the platform proves that combining Direct Attainment calculations, interactive CO-PO mapping matrices, and organically integrated Indirect Attainment surveys into a single, cohesive web application provides unprecedented transparency for academic administrators.

### Future Research Directions

While the current architecture resolves the immediate compliance and computational challenges of NBA accreditation, future iterations of CampusMatrix aim to transition from retrospective analytics to proactive predictive modeling. We intend to integrate supervised Machine Learning algorithms (such as Random Forest classifiers) to analyze early-semester internal assessment data. By recognizing historical data patterns, the system will accurately predict final End-Term Examination attainment probabilities, allowing faculty members to deploy targeted pedagogical interventions for at-risk student cohorts before the academic session concludes. Furthermore, the integration of Natural Language Generation (NLG) models is planned to autonomously author the qualitative text sections of the Self-Assessment Report based on the calculated quantitative trends.

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## Appendix A: Core Source Code Logic

The core Course Outcome (CO) Attainment Calculation Logic is implemented computationally as follows:

```
function calculateCOAttainment(ia_marks, ete_marks, threshold, survey_scores) {

    const ia_attainment = computeThresholdAttainment(ia_marks, threshold);

    const ete_attainment = computeThresholdAttainment(ete_marks, threshold);

    // Direct Attainment formulation based on 30/70 weighting
    const DA = 0.3 * ia_attainment + 0.7 * ete_attainment;

    // Indirect Attainment aggregated from surveys
    const IDA = average(survey_scores);

    // Overall CO formulated on 70/30 weighting
    const overallCO = 0.7 * DA + 0.3 * IDA;

    return { DA, IDA, overallCO };
}
```

## Appendix B: User Manual & Workflow Steps

**Steps to Use the System:**

1. Open the web application in a modern browser and log in with designated role credentials.
2. **Admin Workflow:** Set up department environments, academic sessions, and user accounts.
3. **Faculty Configuration:** Create Course Outcomes (COs) and define CO-PO mapping correlation levels in the dynamic matrix.
4. **Data Ingestion:** Upload student assessment marks (Internal Assessments, quizzes, assignments, lab records, End-Term Exams).
5. **Survey Collection:** Students complete Course Exit Surveys; the system captures these responses for Indirect Attainment (IDA).
6. **Computation:** The system automatically calculates CO attainment (Direct Attainment,

Indirect Attainment, and Overall CO).

7. **Projection:** The system computes PO and PSO attainment dynamically based on the stored CO-PO mapping.
8. **Visualization:** Faculty and HODs view attainment results, trends, and bottlenecks on the interactive dashboard.
9. **Documentation:** Generate, export, and download PDF CO attainment reports and NBA-ready compliance documents.