SMART INDIA HACKATHON 2025

TITLE PAGE

- **Problem Statement ID – SIH25140**
- **Problem Statement Title - Smart Classroom & Timetable Scheduler**
- **Theme – Smart Education**
- **PS Category - Software**
- **Team ID - 93912**
- **Team Name - LUMEN**

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Revolutionary Smart TimeTable System

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PROBLEM REQUIREMENTS

- Secure role-based login for authorized staff with review & approval workflows for timetable management
- Automated optimizer that generates multiple timetables and proposes smart changes when best solution is not available
- Robust multi-department, multi-shift scheduling with conflict-free allocation of resources
- Maximize resources utilization, while minimizing workload for students & faculty
- To account for parameters including real-time availability of faculty, room capacity, teaching load norms, subject combinations, and student preferences

(**UVPs**) UNIQUE VALUE PROPOSITIONs

- Zero-conflict timetables delivered in sub-5-min period, workflow management with parallel-support approval chains - maintaining **competitive-edge in market**
- **NEP-2020 Policy compliance embedded natively**, along with minimum-workload goal on faculty & students, and **multiple critical-objectives optimized**
- **Scalability** → Deployable at both levels, single-institution & national/multiple-institutions by containerization, and institute-centralized databases(data isolation)
- Data validation at multiple stages to ensure **100% error-free scheduling system** services, **error-reports** to address changes when best solution is not available
- **Alternate timetables** to choose from, and **Conditionally-dynamic parameters** system allowing to assign custom parameters & categorize/set them as hard/soft

(**MVP**) MINIMUM VIABLE PRODUCT

CORE – SCHEDULING ENGINE

- Data-model with **over 20 Parameters categorized into hard & soft** in accordance with NEP-2020 Policy; **optional student-batching** as per given parametric data
- **CSV-based system** with input & output validation→integrable with other systems
- **Multi-dimensional analysis** of input complexity to **select best solver**, ensuring optimality
- Incorporates **industry-proven solvers with multiple solution-strategies in modular design** to integrate new solvers, making the model **adaptive**
- Comprehensive **error-reports, and real-time logging** for transparency & issue-traceability, developed entirely in Python

MANAGEMENT SYSTEM

- **Quad-Tier RBAC system** for work-distribution among management hierarchy
- **Intuitive UI/UX & simple architecture** for quick onboarding of users, and developers
- Micro-services architecture for **real-time scaling** of active-users
- **Modular system-design** for efficient & cost-effective development, and to add new features to make system — future-proof
- **Centralized database** per solution/institution for simple & economic maintenance
- **Workflow Grouping** feature to build scalable 2-dimensional approval-loops with notifications of updates

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TECHNICAL APPROACH

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Centralized Database
- PostgreSQL
- Open-source & Time-series recording in-built

(CORE) Scheduling Engine
- Solvers: All major tools & solution strategies,
  eg: Google OR-Tools, PuLP [MIP/CSP Solvers]…
  eg: DEAP, PyGMO [Meta-Heuristic Solvers]…
  (more can be integrated)
- Data-relations/Network Analysis: Python (NetworkX)
- Data & CSV Handling: Python (Pandas+NumPy+SciPy)

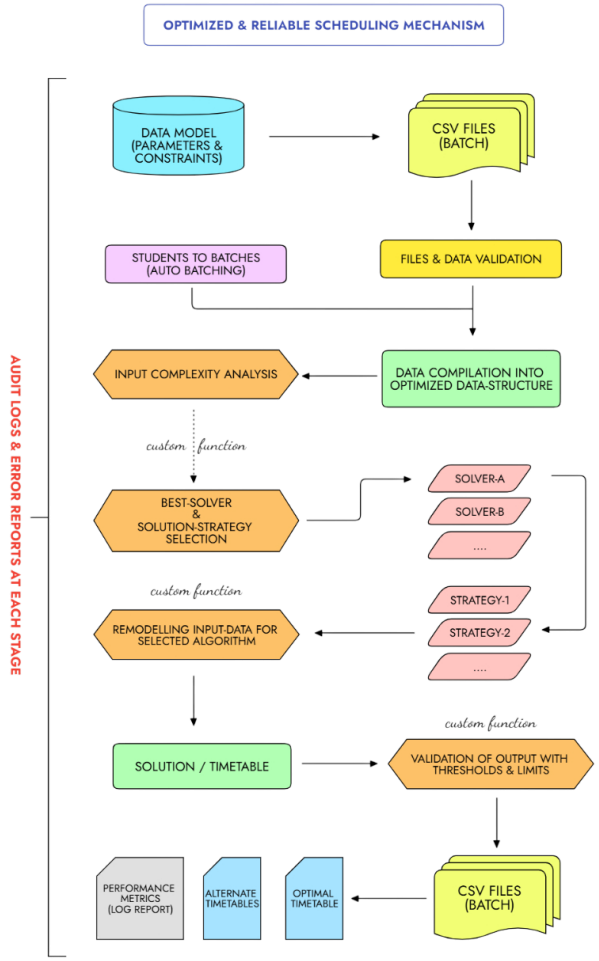
RBAC, Workflow & Auth
- NestJS, Passport.js, JWT

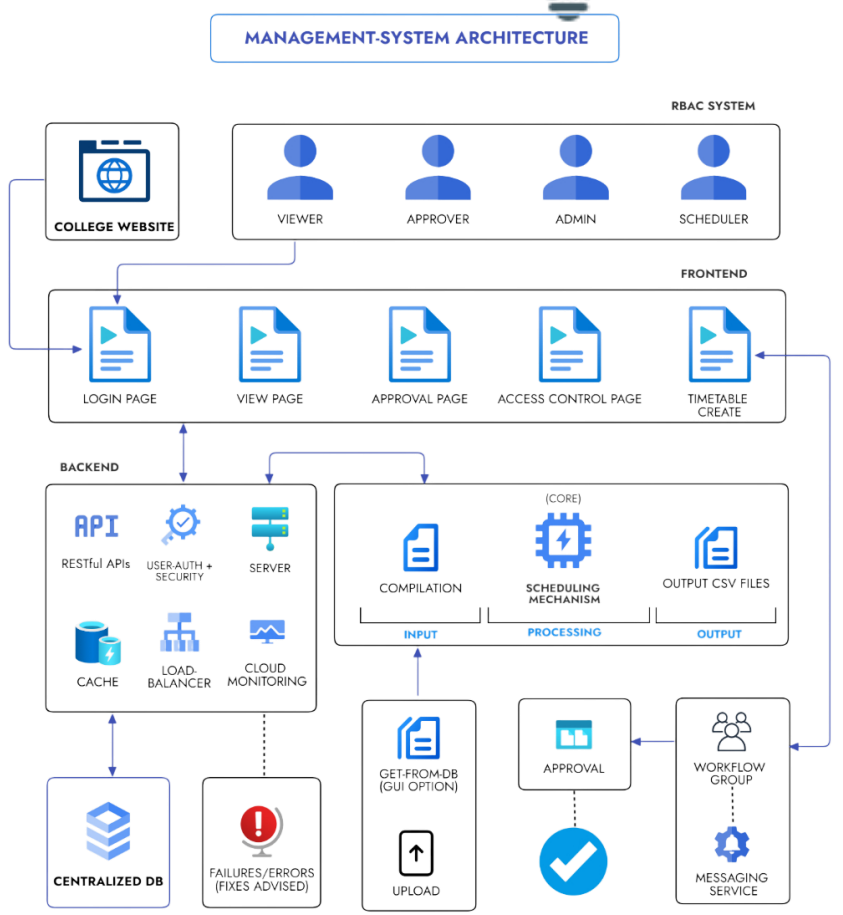
Backend, Caching & API (+ Messaging Service)
- Node.js, Express, RESTful APIs

Frontend
- React, TypeScript, Material-UI
- Mature Ecosystem and role-based routing

Containerization
- Docker
- Scalable container orchestration, auto-scaling and service discovery

GOAL OF INNOVATION
Introduce *special & customized algorithms/functions* to leverage the large-scale research & solutions of Optimization domain to provide effective timetabling solution to the problem





Input Complexity Analysis: *Validates against 16-parameters to evaluate the complexity to select best-solver with optimality, validity*
Feasibility Check: *Quickly conducts checks for infeasibility for given data in 7-layered heuristics to prevent computational cost*
Output Validation: *Evaluates with 7+ threshold variables to define acceptability of solution; 0 tolerance against hard constraints*
Re-modelling Layer: *Mapping real-world entities into math-defined with abstraction in modularity for integration of new solvers*

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FEASIBILITY AND VIABILITY

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TECHNICAL

Feasibility

- Data handling → CSV + Pandas (feasible, widely used in education projects)
- **Complexity scoring** → already implemented with research-backed factors (problem size, constraint density, resource scarcity) → This is technically strong and aligns with real optimization research.
- **Solver integration** → design supports MIP, CSP, Evolutionary Algorithms — state-of-the-art in timetabling problem-solvers.
- OR-Tools is proven in global scheduling systems.

⚠ Solver runtime increases for large datasets

⚠ Integrating diverse constraints (faculty load, room capacity, NEP-2020) rules

⚠ Data inconsistencies in college records (missing or conflicting)

RISKS & SOLUTIONS

✓ Implemented complexity scoring + **solver auto-selection**

✓ Designed a **modular scoring engine** → easy to add new constraints

✓ Added **CSV validation** + default fallback parameters

OPERATIONAL

Feasibility

- Ease of adoption due to **simple architecture**
- Accepts CSV/ERP exports (fits current workflows)
- **Minimal training required** for staff
- Scalability → Works ranging **from small colleges to national-level universities**
- Solver auto-selection ensures **stable performance**
- Maintainability → Modular architecture built-in core-scheduling & management service structure
- **Easy to update** rules & add constraints
- Built-in Load-Balancing & Caching to maintain **optimal system responsiveness** under load

⚠ Different institutions have different timetabling policies

⚠ Staff training & adoption issues

⚠ Scalability to handle many colleges simultaneously

RISKS & SOLUTIONS

✓ Used a **configurable constraint engine** → customizable per institution

✓ Designed intuitive UI + auto-generated reports requiring minimal training

✓ **Cloud-ready** architecture with micro-services architecture, parallel execution-upgradability on solvers

FINANCIAL

Feasibility

- **Low development cost**
- Uses open-source solvers (PuLP, OR-Tools, DEAP, PyGMO, …) → No license fees
- Infrastructure cost → Runs on standard computers/servers for small-medium scale
- Cloud scaling with minimal credits (AWS/GCP/Azure free tier)
- **Revenue potential** → SaaS model for universities/colleges
- **Custom deployments** due to simple-design for government/educational boards.

⚠ Budget limitations in colleges & universities

⚠ High cost of large-scale cloud compute

⚠ Revenue sustainability

RISKS & SOLUTIONS

✓ **Open-source tools** (OR-Tools, OptaPlanner, PuLP …) → zero licensing costs

✓ Optimized to **run on local servers/computers for small-medium problems**; cloud only when scaling onto larger databases

✓ Proposed SaaS subscription model + Collaborative support → predictable cost-sharing.

MARKET

Feasibility

- Demand drivers → NEP 2020 mandates flexible curricula & interdisciplinary timetables
- Growing need for **automation in higher education**
- Target market → Universities, engineering colleges, other HEIs
- Potential integration with ERP/attendance systems
- **Competitive edge** → Our solution = cost-effective, scalable, NEP-aligned.
- **Strong market potential in Indian education sector**.

⚠ Existing ERP systems already handle basic timetabling

⚠ Resistance to adopting new tech in traditional institutions.

⚠ Market awareness is low about optimization benefits

RISKS & SOLUTIONS

✓ Differentiation via **integration AI-driven optimization** + NEP 2020 compliance

✓ Built a simple CSV upload + one-click solver interface → **no technical expertise needed**

✓ Highlighted **time saving advertised** in a demo pitch / published article

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IMPACT AND BENEFITS

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IMPACT

- 85–90% **reduction in manual** scheduling workload
- 95–100% **conflict-free** timetable generation
- 75–90% **improvement in utilization** of resources
- **Sub-5-minute** processing for standard institutional workloads
- 85% faster policy compliance checks
- 70% **fewer scheduling errors** reported
- 30% increase in **stakeholder satisfaction**
- **Supports peak loads** for 1,000+ institutions in multiple-institutional deployment
- **Accelerates semester planning** cycles by 90%, enabling rapid response to curriculum changes
- Supports dynamic rescheduling for emergency scenarios, **reducing downtime** by 80%

BENEFITS

- Automated NEP 2020 compliance, eliminating policy errors
- Centralized multi-tenant management for 1,000+ institutions
- Complete audit trails enhance transparency and **traceability of issues**
- **50% reduction** in operational costs
- Improved management with role-based workflows
- **Scalable & Reliable** cloud deployment minimizes downtime
- Scalability of solver arsenal **encourages industry to explore** new solution methods/strategies
- **Integrated notification** workflows reduce manual follow-ups by 60%

RESEARCH AND REFERENCES

References & Research Work (Full Folder)
(Link-1: https://drive.google.com/drive/folders/1-bsQ5pmvYxxK6O8GlVj9Bq5UwCGiWUyz?usp=sharing)
(Alternate - Link-2: https://www.dropbox.com/scl/fo/csfaehtfi0gi663p6j4h1/AKFGwq3D3kErLLvqMfq8LSg?rlkey=jgz82fmbas85nmgk7v6244lbr&st=rrh6ky90&dl=0)

Prototype (Code Repo with deployed prototype site link)
(Link: https://github.com/snchakri/lumen_25028_ttms)