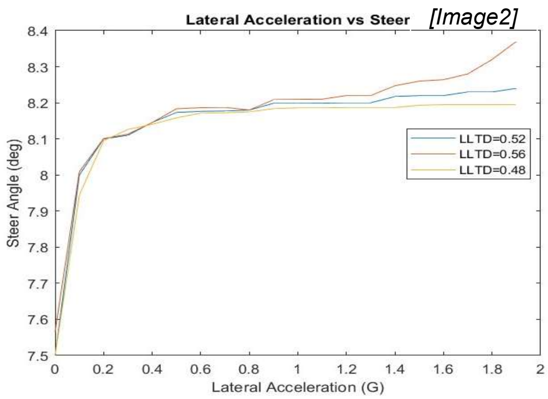
Formula Bharat 2025: Concept Resources Management Report

Through the CRM report, IITK Motorsports presents its unconstrained design ideology, efficient resource utilisation, and strategic project management for its second FSEV.
200+ minutes and 120+ km of testing of the team's first FSEV, participation in FB24 and FB23 Class 1, and feedback from the judges have strengthened our engineering foundation. Our vision is to build the world's best FSEV while strategically navigating the constraints.
The section below outlines our vehicle goals and their importance in excelling as a team and at the dynamic events in a Formula Student competition.

Vehicle goals: The image below highlights the vehicle goals and the derived vehicle specifications that support vehicle performance in different dynamic events. *[Image1]*

Vehicle Goals \ Events	Endurance	Skidpad and AutoX	Acceleration
Dynamically Balanced Vehicle	Ride frequency set at **2.3 Hz**	Lateral Load Transfer Distribution of **0.48** achieved.	Non-0 steering torque at near-0 steer input for linear stability
Reliability and Efficiency	Gear ratio: **4.7,** Weight reduction of **~20 Kg** Target vehicle weight: **240 Kg**	FoS of suspension parts **> 1.5** (A-arms)	FoS of transmission parts **> 1.6** (turnbuckle)
Acceleration and Speed	Optimal weight distribution: CG: x-**53%** from front axle, y-**0mm**, z- **175mm**	Quick acceleration for skidpad, improved lap times for autocross.	Directly implies high straight line speed.

1. **Dynamically balanced vehicle:** Sets the benchmark for the skidpad and autocross events.



[Image2]

- The best skidpad time in Formula Student is **4.43 seconds,** achieved by the unconstrained parameters, our team achieved a simulated skidpad time of **4.60 seconds** on OptimumLap software.
- The LLTD (image 2) of **0.48** was achieved for better cornering, with the ride frequency set to **2.3 Hz**, matching a person's natural walking frequency.

2. **Acceleration and speed:** This goal directly impacts the acceleration event.
   - The best time for acceleration in Formula Student is **3.27 seconds**. The team targeted a peak longitudinal acceleration of **8 m/s²** to achieve competitive times.
   - Comparing various motors, disregarding constraints like cost, inverter availability, and experience, showed that the **AMK DT7** meets our requirements best.

Image 1

Motor Name	Peak Power (0.4)	Peak Torque (0.35)	Weight (0.25)	Total
AMK DT7-17-20-xxO-3500	5	3	5	4.3
Emrax208	4	4	3	3.75
Fischer TI110	3	2	5	3.15
Tsuyo	3	5	1	3.2
Agni 119R	4	2	3	3.05

*The multi-criteria decision-making **(MCDM)** process was employed to evaluate the alternatives.*

- Simulated Acceleration time = **4.46 s**; Peak longitudinal acceleration = **7.56 m/s²**.

3. **Reliability and Efficiency:** Aligns with the Endurance and Efficiency event objectives.
   - Upon analysing endurance times, a target was set to complete the event in **< 23.3 min.**
   - Recognising the high loads on suspension parts during skidpad and stress on transmission parts during acceleration, a **FoS > 1.5** was set for critical components.

   After evaluating various options, Melasta cells were chosen since pouch cells simplify assembly, have UV-weldable tabs with busbars, and high energy volume density.

Cells	Config.	Power (Peak)	Energy	Energy density (kWh/Kg)	Energy density (Wh/cm^3)
Melasta 21 Ah	96s1p	59 kW	7.46 kWh	0.21	0.53
Molicel P45B	96s5p	77.76 kW	7.77 kWh	0.23	0.50
Sony VTC6	96s7p	72.57 kW	7.25 kWh	0.23	0.48
LG M50	96s4p	29.8 kW	6.6 kWh	0.263	0.55 [Image 4]

96S was chosen for easier segmentation and to meet the required energy storage and power output. Lap-time simulation results and parameters for unconstrained vehicle:

- Endurance Time: 1369 s - Required energy: 7.28 kWh, Battery capacity: 7.77 kWh
- Battery: Melasta 21Ah - Battery configuration: 96s1p

Constraints: The team views its constraints as an opportunity to turn limitations into strengths. Points or time losses were also assessed due to each constraint independently.

- Motor & Differential: Constrained by budget, but considering reliability and familiarity, the team decided to continue with the Tsuyo motor, costing 40.5 points in the Acceleration event.

Motor	Cost	Setup	Weight	Acceleration time	Acceleration score
Tsuyo	Already available	Single motor	30 Kg	5.58 s	18.78
AMK DT7	~Rs. 18,20,000*	Quad motor	60 Kg unsprung mass	4.46 s	59.27 [Image 5]

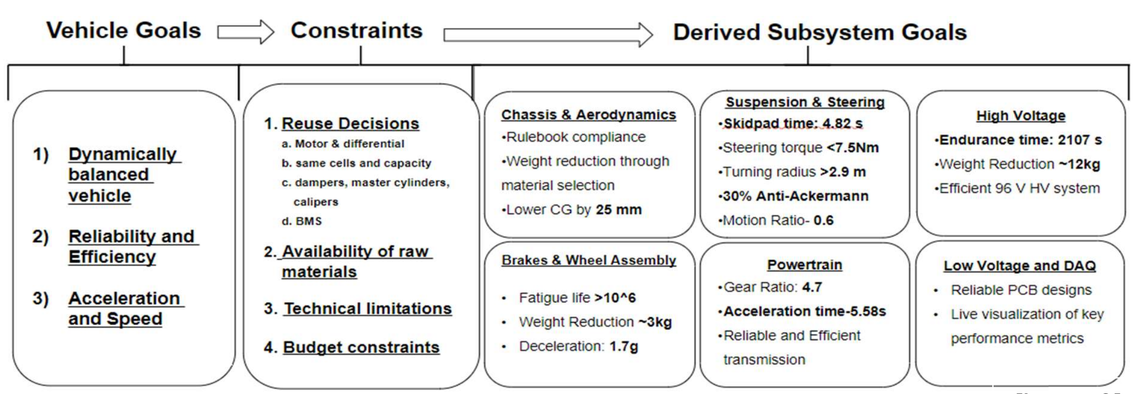
- DNM Dampers, Brake Calipers & Master Cylinders were reused due to familiarity, although performance comparisons for alternatives were made.

Caliper	Cost	Peak deceleration	Rotor material	Rotor weight
Wilwood GP320	Rs. 16,400	2.15g	Titanium grade 5	360 g
Wilwood PS1	Rs. 8,192	1.7g	EN 19	610 g [Image 6]

- Wheels: The team already had 13-inch tires, which would avoid new procurement costs.

Rims	Lateral acceleration	Longitudinal acceleration	Tire cost	Acceleration times (constraint: Rims)	Skidpad times (constraint: Rims)
10-in	2.0 g	2.1 g	Rs. 1,35,000	4.46 s	4.60 s
13-in	1.8 g	1.8 g	available	4.76 s	4.82 s [Image 7]

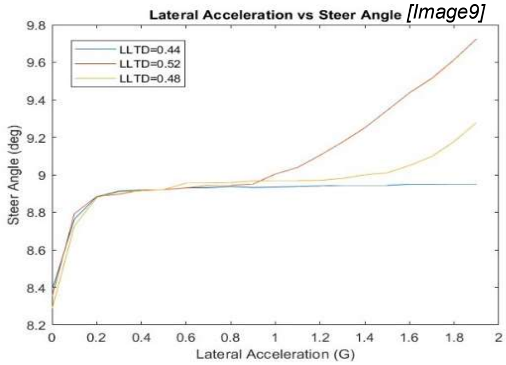
- Lack of availability of crucial raw materials such as Al 7075 blocks, AISI4130 tubes, high-end electrical components, UL-94-rated polycarbonate sheets, etc. around the college.
- Monocoque chassis could reduce the chassis weight from 32 kg to 23 kg but the shift is hindered due to lack of manufacturing resources, technical ineptitude, and budget issues.



Derived subsystem goals: *[Image8]*

A. Suspension and Steering: Setting parameters to achieve the simulated skidpad times.

Retrospective Insights: Excess steering effort, higher CG, uneven tire wear due to camber loss while the minimum turning radius set and achieved on track was 3.7m and 4.5m.



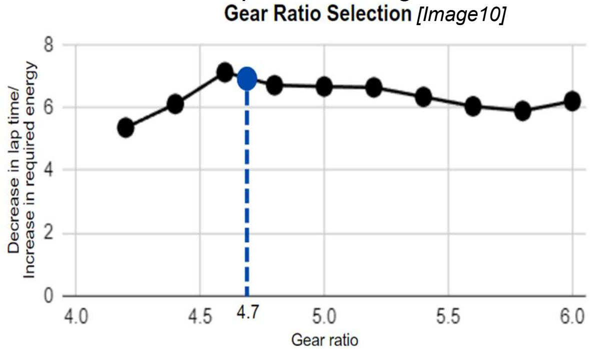
[Image9]

- Utilizing TTC data to precisely calculate the steering torque and limit it to **7.5 Nm**.
- Calculating optimal slip angles and setting a **30% anti-Ackermann** geometry.
- Minimum turning radius is dynamically calculated and set to **2.9 m**.
- The final LLTD value achieved was **0.44**
- The caster angle is set to **3°** to restrict camber loss and uneven tire wear.

The team effectively managed the constraint of using 13-inch rims, which resulted in a minimal increase in skidpad time, from 4.60 seconds to **4.82 seconds**.

B. Powertrain: Optimize gear ratio for endurance with balanced acceleration performance.

- Transmission components designed to withstand extreme loads.



[Image10]

- The **gear ratio (=4.7)** was chosen to maximize lap time reduction relative to the increased energy demand. This gave an **acceleration time** of **5.58 s**.
- Components have a FoS > **1.6** and fatigue life > **10^6** cycles.

Adding four crucial constraints to the comparison matrix, the team found the already available **Tsuyo** motor best suited to their case.

Motor Name	Availability (0.15)	Cost (0.1)	Inverter Availability (0.1)	Experience (0.15)	Previous Total (0.5) Refer Image 1	Total (Out of 5)
AMK DT7	2	2	3	1	4.3	3.1
Emrax208	3	3	3	1	3.75	3.075
Fischer TI110	2	4	3	1	3.15	2.725
Tsuyo	5	5	2	5	3.2	3.8
Agni 119R	4	4	2	1	3.05	2.875 [Image 11]

C. Chassis: Nodes-position optimization for chassis members.

- Achieving higher torsional stiffness (**3708 N/rad**) and lowering CG height (by **25 mm**)
- The spaceframe node positions are derived from a MATLAB model, selecting nodes corresponding to minimum deflection under identical load conditions.

*Material selection was also based on the MCD method and **AISI4130** was selected.*

Alloy	Density (0.25)	Yield strength (0.35)	Availability and Price (0.25)	Weldability (0.15)	Score
AISI4130	10	10	9	8	9.45
AISI1018	10	8	10	10	9.3
AISI1015	10	7	5	9	7.55 [Image 12]

D. Brakes and Wheel Assembly: Reduced weight and increased strength of components.

Retrospective insights**:** Inaccurate dynamic load analysis led to the front hub failure.

- Weight target of knuckle, spindle and hub assembly = **2 kg**.
- Using TTC data helped achieve a higher peak deceleration of **1.7g**.
- Integrated hub and spindle design with FoS **>1.5** and fatigue life **>10^6 cycles**.

E. Aerodynamics: Increasing downforce for higher cornering speed and better handling.

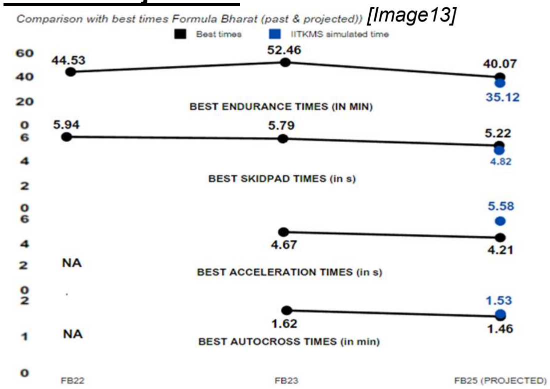
- Limiting drag for better efficiency and greater speed on a straight track.

- Optimized Cl and Cd values to achieve a ratio of **2.5** (Cl: **-2**, Cd: **0.8**).
- A downforce of **695 N** was generated for an average vehicle velocity of 20 m/s.

F. High Voltage: Efficient thermal management and reduction in weight by **12 kg**.
- BMS-controlled cooling ensures optimum fan speed for efficient cooling.
- The vehicle's endurance time was **2107 s (~35 min)**, requiring **3.59 kWh** of energy.
- 24s2p configuration gives an 88.8 V nominal pack voltage, which lies in the controller range of 85-96 V, and 3.7 kWh capacity, and meets the energy requirements.
- Due to the success of last year's Orion BMS 2, we reused the same BMS.

G. Low voltage and Data Acquisition: Reliable PCB designs.
- SMD components on PCBs for noise reduction and optimal signal transmission.
- Over-current and reverse polarity protection and thermal rating for all custom PCBs.
- Open-circuit and short-circuit detection for all sensors used for Data Acquisition.

Points Projection:



[Image13]

- Based on the lap times vs historical and projected best times, the team is positioned to secure 1st place in Endurance (325 pt), Efficiency (100 pt), and Skidpad (75 pt), 2nd in autocross (73.27 pt) and 3rd in Acceleration (18.78 pt), anticipating cumulative dynamic events score of over **592 pt**.
- The team also targets over **290 pt** in the static events, reflecting the historical averages of the winners.

*Our projected score is **882 out of 1000 points**, positioning us to dominate the competition.*

Improvement areas:

The team seeks feedback to identify improvement areas and values external insights while prioritizing introspection. Committed to excellence, we refine strategies and turn limitations into innovative solutions, driving our pursuit of being the best. Key focus areas include:
1. 10-inch rims balance weight reduction with better handling for acceleration and cornering.
2. Lightweight, compact motors and AWD or 4WD systems for improved traction.
3. Regenerative braking converts braking energy into usable power, enhancing efficiency.
4. Anti-roll bar linkage reduces vehicle roll during cornering, allowing for softer spring rates.
5. Liquid cooling stabilizes accumulator temperature and handles extreme conditions better.
6. Undertaking of the development of BMS by the electrical subsystems.
7. Electronics feature negative feedback and voltage detection for precharge circuits, CAN communication for display, and a Vehicle Control Unit for vehicle monitoring.

Tools:

1. **Computational and Analytical Tools:**
   a. Ansys: FEA simulations of components including static analysis and topology optimization of components to obtain deformation, FoS, stress, and strain values.
   b. Ansys Fluent: Cooling analysis of battery pack, CFD analysis of airfoils.
   c. SolidWorks: Design of individual parts along with assembly of the complete vehicle, also used as a tool to validate FEA values from Ansys
   d. Altium: Primary tool for the design and simulation of circuit designs.
   e. Orion CAN software: To configure BMS for the motor controller and charger, and assess battery parameters like temperature and SoC.
   f. Tsuyo Live software for motor tuning and motor controller configuration.

   The team has extensively used modeling and simulation tools like MATLAB, Lotus Shark, and OptimumLap. The Simulations and models are listed in the image.

Subsystem	Input	Output	Utility
Suspension and Steering	VD points, Simulation parameters	Kinematic values Suspension travel	kinematic analysis of suspension geometry in roll, steer, and bump conditions
	Suspension geometry, Lateral/longitudinal acceleration	Forces on arms Roll/ Pitch achieved Steering torque	For dynamic analysis of suspension Finding spring stiffness, upper bounds of the mechanical trail, scrub radius
Brakes and Wheel Assembly	Mass properties, Range of pedal ratio	Clamping force, Dynamic Load transfer, Friction force, Total torque of rotors, Brake line pressure, Heat generated by rotors	For brake pad, Brake Rotor, Brake line selection and analysis
	Mass properties, VD points, Acceleration	Forces on the knuckle Force on the Tire contact patch	forces on every outboard point and the forces on the contact patch for Hub analysis
Powertrain	Motor Parameters, Gear Ratio, Lewis Factor Table Material Properties	Face width FoS for contact failure and bending failure	width and the Factor of safety of the gears for a specific material.
	Mass properties Track parameters	Lap time, Lateral acceleration, Speed	Figure out energy requirements and effective gear ratio for the powertrain.
Chassis	Chassis Geometry Loading and Boundary Conditions Material Properties	Displacements and reaction force at every node Deformation and displacement of every chassis member	Gives the optimized Node positions in the Chassis of the car.
Low Voltage and DAQ	Circuit design schematic	Voltage and current levels for each component in the schematics	Simulation of circuit schematics on SPICE software like Microcap
	Sampling rate, sensor properties, Baud rate	Retrieval of sensors' data	Display and logging of crucial vehicle data- acceleration, speed, gyration angles, etc

[Image 14]

2. Experimental Validation:

a. <u>Individual components</u>: The components are validated through testing in the institute labs, including chassis tube testing, electronic circuits testing on the breadboard, cell performance to assure reliable power delivery, and damper testing.

b. <u>Prototype models</u>: Certain prototype models like PVC tubes chassis, 3D printed sprockets and wooden frames for the accumulator are built to check for compliances.

c. <u>Integrated component testing</u> involves checking the accumulator for reliable power delivery, connecting the motor with the accumulator, and testing the brakes.

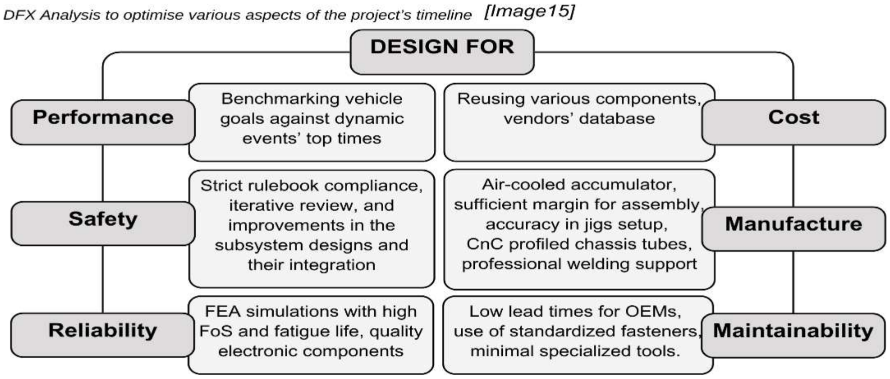
d. <u>Testing the complete vehicle</u>: Comprehensive post-integration testing and data analysis using DAQ systems will evaluate vehicle performance, ensuring competitive readiness and securing points.

3. Design process management:

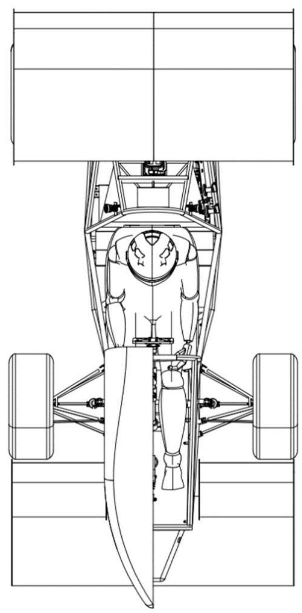
The team uses Bitrix24, to oversee all aspects of team operations, including design, manufacturing, and general tasks. The software's key features are:

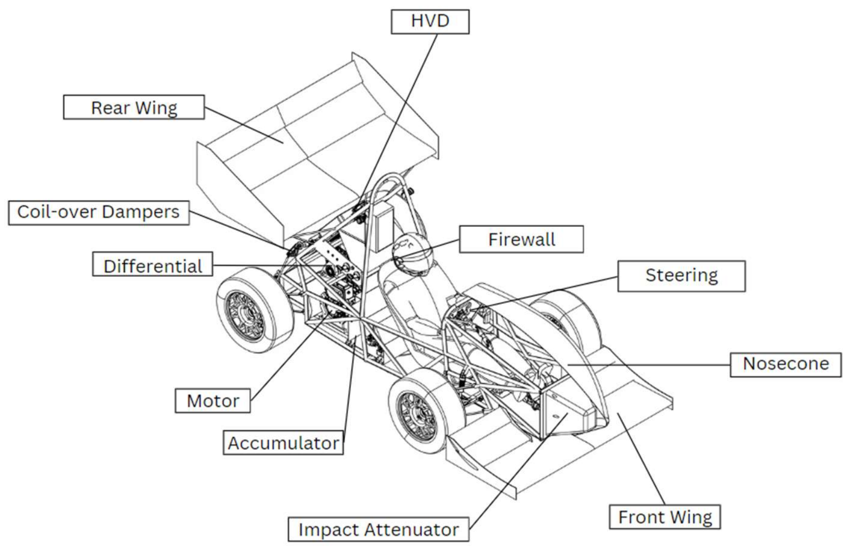
a. Utilizing the Workgroups section, we strategize task allocation, schedule meetings, and formulate subsystem-specific Gantt charts for timeline management.
b. The software's flexible planning chart pattern aids in seamless deadline management.
c. Google Drive is used for file management, designating spaces for each subsystem, ensuring smooth file and data sharing among team members.

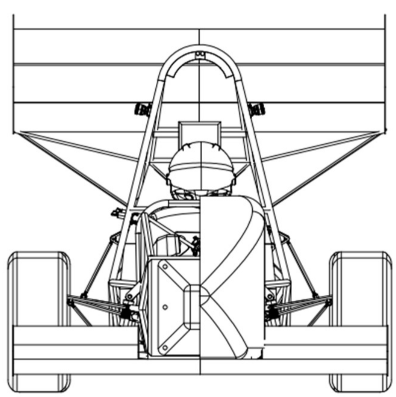
DFX Analysis to optimise various aspects of the project's timeline *[Image15]*

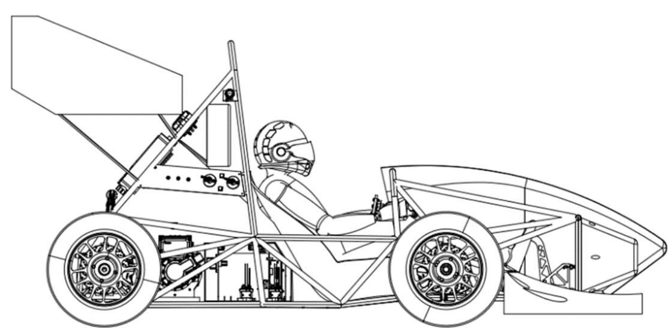


Car parameter	Specification
Top Speed (on track)	100 km/h
Maximum Acceleration/Deceleration	6.36 m/s^2 / 1.7g
Motor Torque/Power	140 Nm/ 30 kW
Vehicle weight	220 Kg
Battery voltage	96 V (Air-cooled)
Battery capacity	3.7 kWh
Battery Configuration	24s2p in 3 segments
Transmission	Chain and sprocket (final drive ratio = 4.7)





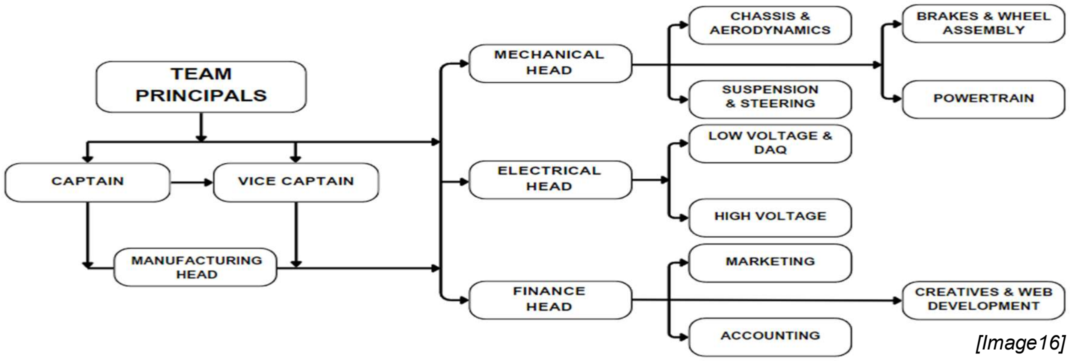




Our design journey began with an unconstrained vision, evolving into a real vehicle defined by optimal use of constraints. In the management section, we'll explore efficient resource utilization and seamless coordination to ensure the success of our Formula Student Electric Vehicle project.

Human Resources:

(1) Team: Each term, the departing and incoming teams rigorously analyze the prior team's performance. This assessment aims to either reaffirm or refine the existing team structure. Such evaluations are instrumental in ensuring that the upcoming season's team objectives are achieved optimally. This season, the following structure has been followed:

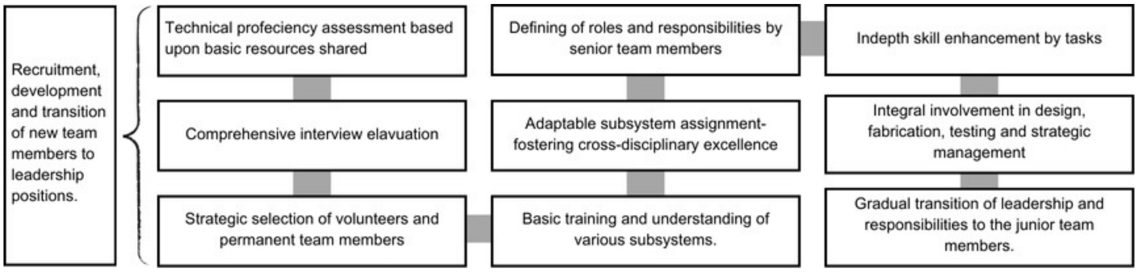


[Image16]

Position (number of people)	Role description	Responsibilities	Skillset
Team Principal (5)	Channelise competition exposure to facilitate faster decision-making and issue resolution as management and technical consultants.	• Guide throughout the project period: design, fabrication, and testing. • Strategize the non-trivial aspects of the team.	• Strategic thinking • Problem-solving • Leadership • Composure
Team Captain (1)	Represents the team, sets objectives ensures timelines, and mediates conflicts.	• Resource allocation (intellectual, material, human) • Integrate project management aspects • Maintain a feedback loop for future strategies.	• Leadership & communication • Project management • Project planning • Resource allocation
Vice-Captain (1)	Manage procurement, JTM development, and Large Group Interactions (LGIs) and Small Group Interactions (SGIs)	• Assists the captain by critically analyzing whether to Implement, modify, or re-structure previously known strategies and decisions. • Keeps note of decisions made for future tenures' reference. • Utilise performance metrics for deeper insights into inefficiencies.	• Analytical skills • Project management • Decision-making • Performance evaluation
Mechanical & Electrical Heads (2)	Integrate subsystems, verify technical objectives, and lead vehicle design and manufacturing.	• Ensure synergy between subsystems.	• Strong technical expertise Design & manufacturing experience • Leadership
Finance Head (1)	Manage finances, marketing, creatives, website, alumni relations, PR events, and sponsor relationships.		• Financial Management Marketing & communication Relationship building
Manufacturing Head (1)	Manage inventory, workshop, procurements, and logistics, Coordinate with other heads for streamlined manufacturing.		• Supply chain management Logistics & inventory control Workshop management
Subsystem Head (6)	Lead a specific subsystem	• Ensure technical goal alignment with team objectives and vehicle goals • Facilitate communication between STMs and JTMs.	• Expertise in the specific subsystem • Communication & collaboration skills
Senior Technical Member (STM) (6)	Mentor JTMs, Assign tasks	• Designing and manufacturing the vehicle • Ensuring timeline implementation and work distribution at the subsystem level.	• Strong technical expertise in relevant field • Communication & mentorship skills
Junior Technical Member (JTM) (42)	Participate actively in design, contribute to assessments, and engage in manufacturing, guided by STMs		• Eagerness to learn • Technical aptitude

[Image 17]

[Image 18]



To keep the sub-team responsible for the Team Project Management in check and define parameters for excellence in management, we have set in place **performance metrics** and **evaluation methods**.

Trait	KPIs	Explanation	Target
Leadership	Retention rate	Number of members in the team vs those available at the start of the evaluation cycle.	>80 %
Management	Task completion rate	The percentage of tasks completed on time at the end of the evaluation cycle	>90%
	Budget variance	Deviation from the allocated budget	<5%
Communication	Meeting frequency	Number of meetings held per month	>2 LGIs, >5 SGIs
Stakeholder engagement	Sponsor retention, Outreach events	Percentage of sponsors retained from one project cycle to the next, number of outreach events.	>75%, >2 per semester *[Image19]*

These metrics are calculated through general but **effective evaluation** methods:

a. <u>All-round feedback</u>: Taking quarterly feedback based on uniformly scaled metrics from team members, faculty advisors, sponsors, and administration through forms.

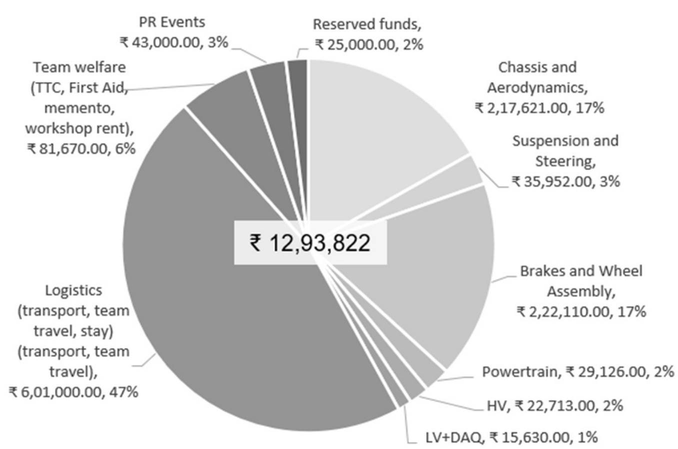
b. <u>Objective measurements</u>: Maintaining progress reports, and budget reports and tracking the timeline gives direct insight into the defined **KPIs**.

2. Partners: The marketing and finance team, alongside the technical team, identifies potential partners, including MNCs, educational institutions, and OEM vendors, to secure funding and vital parts. Alumni and staff also contribute their experience and knowledge. The team has also retained sponsors from the last season with a retention rate of 72.2%.

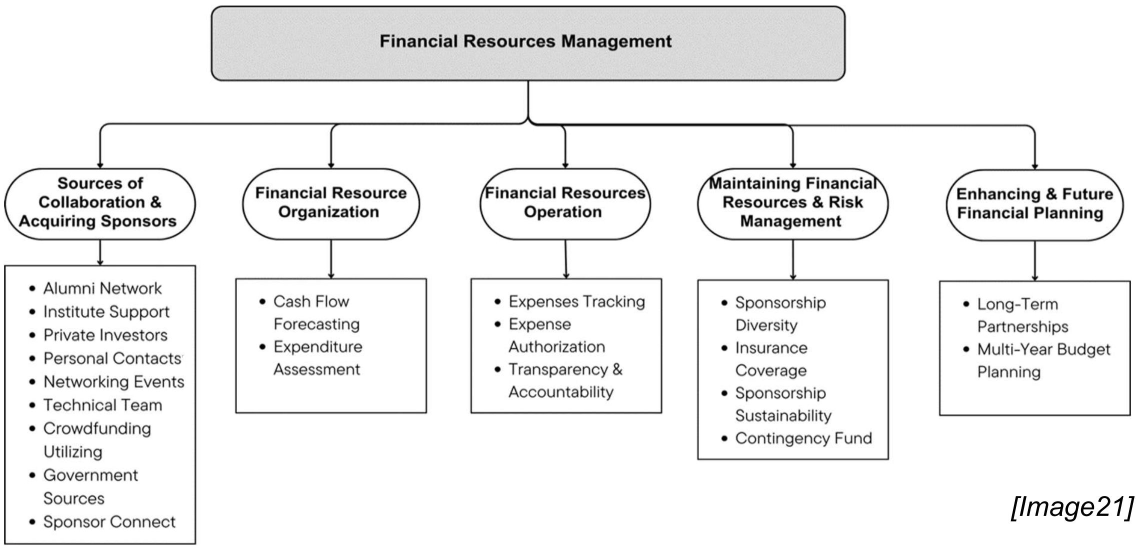
- <u>Sustaining of partners:</u> Establish partnerships through MOUs and sponsorship contracts, defining mutual benefits and risk mitigation. Maintain open communication and provide regular updates through monthly progress reports and quarterly meetings.
- <u>Events and Activities:</u> The team strategically organizes events year-round to maintain a strong presence and actively engage with the campus community and partners.

<u>Financial Resources Management</u>

The team's financial goals involve strategic planning, allocation, and utilization of funds to meet yearly objectives. The total budget for the season 2024-25, covering components, manufacturing, competition, and operational costs is approximately INR **12.94 lakhs** with a **~2%** flexibility margin. The pie chart shows the subsystem-wise budget breakdown.



Budget Breakdown [Image20]



[Image21]

Manufacturing Resource Management

Specifying
• Identify and assess resources for vehicle design, development, and manufacturing, maintaining a prioritized list based on complexity, resources, and time constraints.
Acquiring
• In-house Manufacturing: The team utilizes institute facilities such as the Central Workshop, Power and Electronics Lab, Tinkering and Imagineering Lab, and 3D printing facilities for welding, fabrication, and assembly. The Advanced Centre of Materials Lab, Structural Engineering Lab, and National Wind Tunnel Facility are vital for component testing. The institute also provides a dedicated workspace for the team to function. • In-kind Support: Collaborates with vendors for discounts, partners with startups/companies for workshops/testing, and receives logistics support.
Organizing
• Inventory Management: Maintaining inventory reports of essential resources, equipment, tools, materials, and components to allocate them throughout the project's development phases.
• Pooling of Resources: Being a part of the Science and Technology Council of the institute, the team has access to the resources and equipment of other teams and clubs.
• Workshop Organization & Safety Protocols: Systematically categorizing, organizing, and labelling resources to enhance accessibility. Additionally, proper safety guidelines are established for team members operating the equipment.
Operating
• Training: Conducting training sessions led by experienced professionals to educate team members on proper operation and handling of testing equipment.
• Workflow Planning: Dividing the work into shifts as per the team members to smoothen the workflow and ensure efficient allocation of human resources.
Maintaining
• Regular Inspection: Assessing and maintaining inventory, equipment, and tools for optimal performance, including cleaning, lubrication, repairs, and timely replacement of consumables like cutting tools and grinding wheels.
• Performance tracking and enhancement: Periodically assessing vendor performance in terms of quality, timeliness, and reliability, and documenting them.
Enhancing
• Skill Development: Team members are involved in various independent research projects led by professors, aiming to enhance the testing and manufacturing processes. • Long-Term Investment: Investing in better equipment, tools, and inventory management facilities to better organize the team resources for future projects.

[Image 22]

Task Management

The team also utilizes Bitrix24 software to manage operations, communicate and coordinate effectively. Additionally, in-person meetings further foster teamwork and goal achievement. The following highlights the software's features and our utilization for this purpose.

❖ **Management (Inventory & Operations):**

- Vendor and Company Logs: Maintain records of organizational contacts and procurement specifics in the Inventory Management tab.
- Inventory Oversight: Oversee inventory and log all accessible hardware resources.

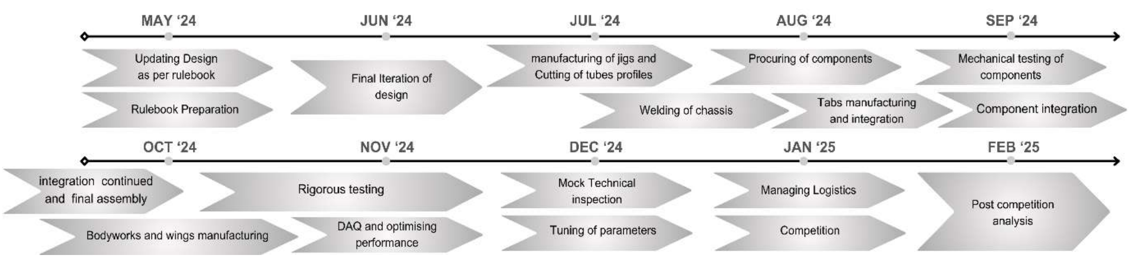
❖ **Communication:**

- Chat and Call Features: Streamline information exchange and direct communication within the team, minimizing misunderstandings.
- Dynamic POCs: Maintain Points of Contact for subsystem tasks in the Company tab, ensuring coverage if a member is unavailable.
- Feed Tab: Provide general updates, including meeting minutes and work progress.

❖ **Coordination:**

- **Event Calendar:** Monitor important deadlines and submission dates.
- **Mobile Accessibility:** Manage projects and communicate on-the-go.
- **CRM Integration:** Access Instagram, Facebook, and LinkedIn pages to track communications and requests from vendors and sponsors.

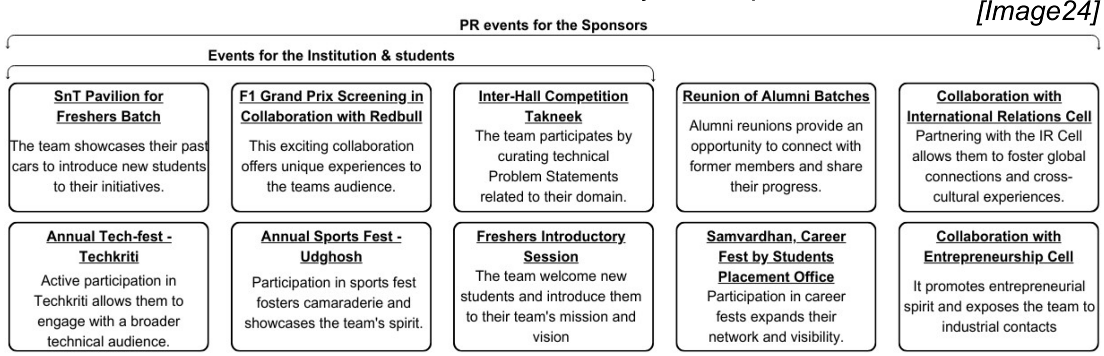
[Image23]



The team conducts two types of in-person meetings: LGIs (Large Group Interactions) with the full team and inter-subsystem meetings, and SGIs (Small Group Interactions) within the subsystem. LGIs follow protocols, while SGIs are more frequent and harder to manage.

- Pre-Meeting Agenda: A clear pre-meeting agenda is released before each meeting.
- Rotation of SGI Facilitators: Different people take turns leading small group meetings.
- 360° Feedback: Everyone's feedback is actively sought and considered.
- Minutes of Meeting: Detailed meeting minutes are maintained to keep track of discussions and decisions this ensures that everyone is up to date.

[Image24]



The team strives to build lasting connections within our community, promoting collaboration, knowledge sharing, and mutual support. These events serve as a bridge that unites our stakeholders and enhances the team's overall mission.

In Conclusion: At the core, all team members of IITK Motorsports are driven by the dedication to build a top-notch team and vehicle and represent their institution globally. Our shared goals, transparent updates, defined roles, and inclusive culture strengthen our unity. As rightly implied by Claude Rouelle, making an A team and a C car is vital, trying to make an A car with a C team will lead to pointing fingers and destroy the team's morale.