

ASSESSMENT LEVEL 7

Title: Optimisation of UWTSD Race Vehicles Body and Chassis.

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Abstract

This report addresses the Engineering Design and Simulation module assignment by investigating optimisation methods for the suspension setup of an SRCC Sports 2000 Duratec race car available at UWTSD. Focusing on body and chassis subsystem improvement within strict regulatory constraints. The SRCC Sports 2000 Duratec Championship employs open-cockpit, rear-engine vehicles powered by production 2.0L Ford Duratec engines, where performance gains depend heavily on chassis and suspension tuning rather than engine power.

A conceptual surrogate-based multi-objective optimisation workflow is proposed, targeting realistic design variables including front & rear spring rates, two-way damper settings, driver-adjustable anti-roll bars and static camber alignment. Using steady-state vehicle dynamics modelling coupled with design of experiments, kriging surrogate construction and genetic algorithms, the approach aims to maximise cornering grip, stability and tyre life while respecting material restrictions, safety standards and flat-floor geometry requirements.

Expected outcomes include balanced roll stiffness distribution, optimal tyre operating windows and progressive compliance for UK circuits. Critical evaluation acknowledges limitations of steady-state modelling versus transitional dynamics, proprietary tyre data uncertainty, driver variability and practical barriers like chassis hardpoints and team budgets. The methodology demonstrates safety benefits, cost control through reduced tyre wear, and enhanced driver confidence, evidencing Level 7 competence in analytical technique selection, design judgement and consideration of wider engineering context.

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1. Introduction

This assignment investigates optimisation methods and evaluates how they can be applied to the body or chassis of a UWTSD race vehicle. The report focuses specifically on suspension optimisation for the Sports 2000 Duratec car, as suspension parameters such as springs, dampers, anti-roll bars and alignment offer meaningful performance gains within the strict regulatory framework. Suspension tuning directly affects tyre grip, stability, driver confidence and tyre life, making it a suitable subsystem for demonstrating optimisation principles.

Motorsport championships such as SRCC Sports 2000 Duratec (SRCC, 2025) use tightly controlled technical regulations to balance performance, safety and cost for competitors. In this series, cars are open-cockpit, rear-engined, two-seater sports racing cars powered by a production-based 2.0 litre Ford Duratec engine, with strict limits on aerodynamic devices, engine tuning and chassis construction. As a result, a significant proportion of performance comes from how effectively teams design and tune the chassis and suspension rather than from outright power.

The report first reviews contemporary optimisation tools relevant to engineering and motorsport. It then defines a conceptual suspension optimisation problem and outlines a feasible workflow for a Sports 2000 Duratec car. Finally, it critically evaluates the limitations of the proposed approach and discusses its implications for safety, performance and regulatory compliance.

2. Literature Review: Optimisation Tools

2.1 Optimisation in motorsport and vehicle dynamics

In engineering, optimisation refers to the systematic selection of design variables to maximise or minimise one or more objective functions while satisfying a set of constraints, as described in standard design texts on engineering optimisation (Tartibu, 2025). In race car engineering, key objectives focus on reducing lap time, enhancing tyre life, improving stability, and boosting driver confidence, while adhering to safety regulations, cost constraints, and technical rules like those of the SRCC Sports 2000 Duratec Championship. Vehicle dynamics studies often approach suspension tuning, weight distribution, and aerodynamic balance as constrained optimisation problems. Connecting design decisions to performance metrics such as lateral acceleration and lap time (Jiménez Elbal, et al., 2024). Motorsport optimisation focuses on subsystems that significantly impact vehicle performance while keeping to regulations. Key areas include suspension geometry, aerodynamic balance, weight distribution, and gear ratios. Which can be optimised for specific circuits and drivers. Figure 1 shows the race vehicle used by UWTSO in the 2025 Duratec 2000 sport race.



Figure 1. UWTSO SRCC Duratec car.

Because modern racing series like Sports 2000 Duratec tightly control engines and aerodynamic devices, competitive advantage often depends on how effectively teams use analytical and simulation tools to optimise the chassis and suspension within the allowed ranges (SRCC, 2025). This aligns with broader motorsport practice, where vehicle models coupled with optimisation algorithms are routinely used to support setup decisions rather than relying solely on driver

feedback and trial-and-error testing. In this assignment, optimisation is therefore treated as a conceptual framework for making structured suspension setup decisions, rather than as a fully implemented numerical lap-time optimisation, which reflects how optimisation methods are introduced in advanced vehicle dynamics and motorsport engineering literature.

2.2 Classical optimisation methods

Classical optimisation methods rely on smooth, differentiable models and therefore perform well when suspension behaviour is locally linear, and the design space is unidirectional. Their main limitation is sensitivity to initial conditions and their inability to escape local optimisation, which restricts their usefulness in highly non-linear vehicle dynamics problems. Although DoE and surrogate modelling reduce computational cost, they still depend on the quality of the underlying model and may misrepresent behaviour in regions with strong non-linearities. This highlights why classical methods are often supplemented or replaced by global search techniques in motorsport applications (Rao, 2019).

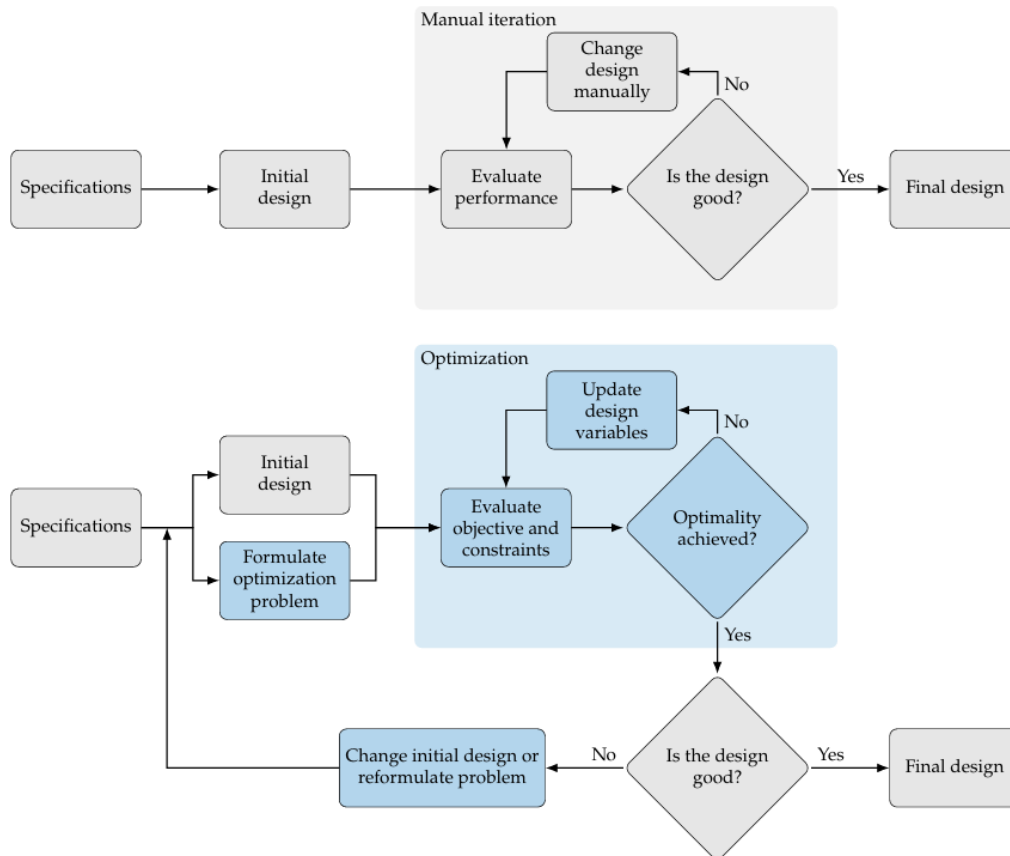


Figure 2. Traditional [Top] vs Design Optimisation Process [Bottom] (Martins & Ning, 2021).

Gradient-based algorithms, including steepest descent, conjugate-gradient methods, and sequential quadratic programming, are effective for optimization when derivatives of objectives and constraints are available or can be approximated (Martins & Ning, 2021). They converge quickly to local optima in smooth and unimodal design spaces, such as when adjusting suspension parameters. However, their effectiveness decreases in strongly non-linear or multi-modal scenarios where multiple local optima exist and obtaining derivative information may be challenging or costly.

To reduce the costs of evaluating high-fidelity simulation models, classical workflows often utilise Design of Experiments (DoE) alongside surrogate models. This involves generating a structured set of design points through methods like factorial designs and Latin hypercube sampling. Each point is evaluated using the full model, and a surrogate model, such as polynomial response surfaces, approximates the data for future optimisations, significantly lowering computation time. This technique is effectively used in vehicle suspension problems, where response surface models help in efficient multi-objective optimization of handling metrics (Thoresson, et al., 2009).

Classical optimization methods for the Sports 2000 Duratec suspension include gradient-based algorithms for small parameter sets around known operating points, and Design of Experiments (DoE) with surrogate modelling to navigate broader design spaces when simulations are costly (Callejo Goena, 2013).

2.3 Modern and AI-based techniques

Modern optimisation approaches, including evolutionary algorithms and metaheuristics, have gained popularity in solving suspension and vehicle dynamics issues due to advancements in vehicle models and computing power. Techniques like genetic algorithms, particle swarm optimisation, and differential evolution do not require gradient information, allowing them to effectively navigate complex, non-linear, and multi-modal design spaces, making them particularly suitable for suspension design, which involves interdependent objectives such as ride comfort, road holding, and handling stability (Baumal, et al., 1998; Yu & Yu, 2003).

Numerous studies have utilised genetic algorithms (GAs) for suspension optimisation, adjusting parameters like damper coefficients and spring rates to reduce sprung-mass acceleration and enhance comfort and handling. GA-based methods have demonstrated superior global search

capabilities over traditional optimisation techniques in identifying optimal passive suspension parameters for various vehicle models, despite imposing a higher computational burden (Mitra, et al., 2016). Additionally, some research has integrated GAs with classical methods, leveraging global search for initial parameter location and local algorithms for refinement, thus combining the strengths of both strategies.

Data-driven and AI-based techniques, including machine learning models like neural networks, have been introduced for optimizing race car setups. These models can predict performance metrics from suspension parameters based on simulation data or telemetry. Once trained, they allow for rapid exploration of design options and enable population-based optimisation algorithms. Industrial tools now incorporate AI-powered surrogate modelling and optimisation for vehicle and chassis development, balancing dynamics, cost, and safety (AVL, 2026).

In motorsport, AI-assisted workflows enhance traditional driver-in-the-loop tuning by recommending setup directions, thus minimising necessary track tests for achieving competitive configurations. The assignment on the Sports 2000 Duratec suspension emphasises the relevance of combining multi-objective global search methods with data-driven surrogate models to effectively explore suspension options, even with complex vehicle dynamics and regulatory constraints (Pickering, 2024).

3. Vehicle and Suspension Context

3.1 SRCC Sports 2000 Duratec car description

The SRCC Sports 2000 Duratec Championship is a UK motorsport series for rear-engine, two-seater sports cars that utilise a standard 2000 cc Duratec engine. Governed by Motorsport UK National Competition Rules and the FIA International Sporting Code, the championship prioritises safety, cost control, and competitor parity. It features strict technical regulations limiting engine modifications and ensuring compliance with safety standards for various components, including chassis, braking, and fuel systems (SRCC, 2025). Figure 3 shows the race car model form UWTSD according to the regulations of SRCC.



Figure 3. SRCC Sports 2000 Duratec car from UWTSD.

To ensure safety and performance, cars are designed with a steel structure featuring an impact-absorbing front and a flat underside, while minimizing ground-effect devices to control aerodynamic costs. The bodywork encompasses essential mechanical parts like wheels and suspension, adhering to guidelines for cockpit size and driver safety. Performance improvements largely come from optimising the chassis, suspension, and tyres rather than increasing engine power, highlighting the importance of suspension optimisation strategies (SRCC, 2025).

3.2 Suspension regulations and design freedom

The Sports 2000 Duratec technical regulations mandate that cars have a sprung suspension system to prevent wheel or tyre fouling with the bodywork or chassis. While chassis construction is largely unrestricted, it must be metallic, excluding carbon fibre composites, and adhere to a flat-floor design to limit ground-effect aerodynamics. Additionally, Motorsport UK Section K safety requirements apply to chassis integrity, wheel and tyre specifications, and braking systems, impacting suspension geometry and packaging (SRCC, 2025).

Suspension components in vehicles must generally be metallic, with springs made of steel, although there is flexibility in layout and kinematics if safety and dimensional rules are met. Shock absorber designs are free but must not include active or driver-adjustable systems; dampers are

limited to two-way adjustability. Driver-adjustable front and rear anti-roll bars are allowed, providing tuning options for roll stiffness. Despite restrictions on advanced technologies and materials to control costs, there is considerable freedom in suspension geometry and setup, making it a key area for optimisation in this assignment (SRCC, 2025).

Although the Sports 2000 regulations restrict advanced technologies such as active suspension, carbon-composite components and multi-way adjustable dampers, they still allow meaningful tuning freedom. Teams can vary spring rates, damper settings, anti-roll bar stiffness and wheel alignment within practical and regulatory limits. This creates a constrained but sufficiently rich design space for optimisation. However, fixed chassis hardpoints and flat-floor requirements limit the extent of geometric changes, meaning optimisation must focus on setup parameters rather than fundamental redesign.

4. Proposed Suspension Optimisation

4.1 Problem definition

In this assignment, the focus is on optimising the suspension setup of a Sports 2000 Duratec car by adjusting parameters like spring rates, damper settings, anti-roll bar stiffness, and wheel alignment. These adjustments aim to influence load transfer and tyre contact patch behaviour, thereby impacting the vehicle's handling characteristics and tyre usage during a race.

The performance objectives focus on enhancing cornering grip, high-speed stability, and driver confidence while managing tyre wear for consistent race performance. The setup must withstand track irregularities and avoid excessive nervousness that could affect safety and controllability. This leads to a multi-objective optimisation challenge, balancing competing targets like maximum grip, predictability, and tyre longevity.

All proposed changes must comply with the SRCC Sports 2000 Duratec technical regulations and Motorsport UK safety requirements, which encompass a sprung suspension system, material restrictions, damper adjustability limits, and constraints on ride height and body motion due to flat-floor and bodywork rules. The challenge lies in selecting a viable combination of suspension setup parameters that align with specified handling and durability objectives, which will be elaborated upon in the subsequent subsections.

4.2 Design variables

The primary design variables are the front and rear main spring rates, which control the overall stiffness of the suspension and strongly influence roll stiffness distribution, pitch behaviour and ride characteristics. Complementing these are the bump and rebound settings of the dampers at each axle, constrained to the ranges available on a two-way adjustable passive damper in accordance with the regulations. Additional variables include the effective stiffness settings of the front and rear anti-roll bars, which may be altered via blade position or lever arm geometry and, where fitted, adjusted by the driver from the cockpit. Finally, static wheel alignment parameters, specifically camber and toe angles at the front and rear, are included as design variables within practical ranges that respect tyre clearance, steering geometry and regulatory limits. Together, this set of variables defines a multi-dimensional design space in which different suspension setups can be evaluated and compared using the optimisation framework described later.

4.3 Conceptual modelling and optimisation workflow

The optimisation conceptual model is a simplified steady-state vehicle dynamics system focusing on lateral acceleration. It uses suspension setup variables to calculate outputs like lateral load transfer distribution, tyre normal loads, contact patch utilisation, and stability indicators. Tyre behaviour is estimated through a simplified model linking normal load, camber, and slip angle to lateral force capability, thus providing a grip potential proxy without needing proprietary data. This modelling approach suits conceptual design and setup optimisation, as it effectively captures the main impacts of suspension parameters while being computationally efficient (Velenis, et al., 2009; Edelmann, et al., 2011).

The optimisation workflow follows a classical surrogate-based approach adapted for multi-objective problems, as follows:

Define design space: set realistic bounds and constraints for each design variable based on practical setup ranges, regulatory limits and packaging considerations (Yang, et al., 2016).

Design of Experiments (DoE): Generate a structured sample of 50–100 suspension setups using Latin hypercube sampling across the design space and evaluate each using the steady-state model to produce a dataset of objective values (Yang, et al., 2016).

Surrogate model construction: Fit a response surface or kriging model to the DoE dataset, approximating the relationship between suspension variables and performance metrics such as grip potential, load balance and tyre utilisation (Song, et al., 2026).

Multi-objective optimisation: Apply a population-based algorithm such as a genetic algorithm to the surrogate model, searching for Pareto-optimal setups that represent the best trade-offs between competing objectives (Florea, et al., 2016).

Select and validate: Choose a compromise solution from the Pareto front suitable for a typical championship circuit and assess its sensitivity to parameter variations or model uncertainties (Khan, 2020).

The conceptual model uses steady-state lateral dynamics to estimate load transfer, tyre utilisation and balance. Although this approach does not capture transient behaviour, it is appropriate for early-stage optimisation because steady-state cornering dominates lap-time sensitivity and provides a computationally efficient basis for exploring the design space. The workflow combines DoE, surrogate modelling and multi-objective optimisation to identify Pareto-optimal setups that balance grip, stability and tyre wear.

4.4 Expected outcomes

The optimisation is expected to yield a suspension setup with balanced roll stiffness distribution that maximises steady-state cornering grip while maintaining predictable handling characteristics. Camber and toe settings should emerge that keep tyres within optimal operating windows for the championship Hoosier control tyres, improving both peak grip and wear characteristics. Spring and damper rates are likely to favour progressive compliance for kerb riding while providing sufficient control for high-speed stability. Anti-roll bar settings would adjust front-to-rear balance for neutral handling on typical UK circuits. These outcomes provide a defensible starting point for track testing within regulatory constraints.

4.5 Wider Engineering Considerations

The proposed suspension optimisation supports several wider engineering requirements beyond performance. From a safety perspective, a balanced setup improves stability, reduces sudden oversteer or understeer, and helps maintain predictable tyre behaviour. Aligning with Motorsport UK Section K and SRCC technical regulations. Optimising tyre load distribution also reduces overheating and uneven wear, offering environmental benefits through lower tyre consumption and fewer test laps. For university teams operating under tight budgets, improved tyre life and reduced trial-and-error testing provide clear commercial advantages, lowering running costs and minimising component fatigue or damage. The approach also meets user needs, giving drivers more confidence and a consistent vehicle. Additionally, offering students a structured, industry-aligned engineering workflow. Collectively, these factors demonstrate responsible design judgement that considers safety, sustainability, cost control and regulatory compliance alongside performance.

5. Critical Evaluation of the Proposal

5.1 Limitations of models and data

While the steady-state model captures fundamental load transfer mechanisms, it cannot represent intermittent behaviours such as turn-in response, kerb strikes or combined braking-cornering events. These effects can dominate driver perception and may cause variations between model-predicted and real-world balance. Furthermore, surrogate models introduce approximation error, particularly in regions of limited sampling, and their accuracy depends heavily on the DoE distribution. Without proprietary tyre data, the model must rely on simplified load-sensitivity curves, which limits predictive accuracy.

5.2 Practical and regulatory limitations

Suspension geometry is constrained by existing chassis hard-points and packaging, limiting the scope of achievable kinematic changes without major redesign. Regulations prohibit active systems, advanced damper adjustability and exotic materials, restricting access to potentially superior technologies. Small racing teams face budget and time constraints that limit both

computational resources for surrogate model refinement and track testing iterations needed for validation. While the workflow provides structured guidance, real-world implementation requires compromise between theoretical optima and practical feasibility within regulatory and operational boundaries.

6. Conclusion

This report has demonstrated how optimisation concepts can be applied systematically to the suspension setup of an SRCC Sports 2000 Duratec race car, addressing the module requirements for evaluating optimisation tools and applying them within a regulated motorsport environment. By reviewing classical, modern and AI-assisted optimisation methods, the work showed how surrogate-based, multi-objective techniques provide an efficient and defensible approach for exploring spring rates, damper settings, anti-roll bars and alignment within realistic constraints.

The proposed workflow aligns with AHEP4 learning outcomes by integrating mathematical modelling, critical evaluation of computational techniques and informed engineering judgement. While the steady-state model and simplified tyre behaviour introduce limitations, the approach remains appropriate for conceptual optimisation and highlights where further validation or brief analysis would be required. The method also supports wider engineering considerations, including improved safety through predictable handling, reduced environmental impact via lower tyre consumption, and commercial benefits for teams operating under budget and testing constraints. Overall, the study demonstrates a coherent and responsible application of optimisation methods that balances performance, practicality and regulatory compliance.

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