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Crashworthiness and Occupant Protection of a Modified Seat
Leon TCR

Automotive Chassis Systems (ACHA5013)

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Introduction

This report looks at the crashworthiness and occupant protection of a Seat Leon that has been modified to comply with FIA TCR regulations. There are many safety features that are implemented into cars today to meet regulations, including various airbags, belt pretensioners and autonomous emergency braking (AEB). These features are important as they protect occupants, pedestrians and other road users by minimising the impact of crashes, therefore reducing injuries and fatalities. Additionally, some features are being added to newer cars to help prevent crashes, such as blind spot detection and adaptive cruise control.

Whilst some safety standards within cars are due to laws, such as seat belts being mandatory in vehicles, many of the safety standards are a result of the work performed by the European New Car Assessment Program, Euro NCAP (*Seat belts in cars and dual purpose vehicles*, 2026). Euro NCAP is an independent organisation that provides crash test results and safety ratings for cars sold in Europe (*Euro NCAP | About Euro NCAP | Who we are and what we do*, 2026). Euro NCAP crash tests cars through a series of different tests that are designed to replicate everyday road accidents. These tests include frontal impacts and side impacts. The tests are also performed using a range of crash dummies to gain an understanding of how a range of people of different shapes and sizes are affected during a crash, ensuring safety standards can be inclusive (*Euro NCAP | How cars are tested | Safety requirements*, 2026).

Safety features in road cars focus on the safety of the occupants as well as pedestrians, whereas the safety features needed in TCR cars are focused on protecting the driver in high-speed track incidents. Road cars also need to consider practical constraints, such as comfort, noise and cost. On the other hand, TCR cars concentrate on performance capabilities meaning the cars are usually stripped of excess weight and are modified to enhance racing performance. Testing the safety, and therefore the safety features, in road cars focuses on the most common types of collisions. These collisions differ to those in racing due to factors such as speed, and consequently the safety features in a race car need to be different. This leads to the modification of standard road cars used in racing.

Seat Leon Safety

In 2012, Euro NCAP tested a Seat Leon in which it received five out of five stars. It achieved 94% in adult occupant safety, 92% in child occupant safety, 70% in pedestrian safety and 71% in safety assist (Euro NCAP, 2012). The tests performed were the frontal impact, the side impact and the pole test. The Seat Leon safety features included driver and front passenger airbags, front side airbags, two curtain airbags, driver's knee airbag, electronic stability control with emergency brake assist, automatic post collision braking system and seat belt reminders ('Seat-Leon-2015-UK', 2015). Whilst the 2012 Euro NCAP report is no longer available, the 2020 test received similar results, with the largest difference being an increase to 80% in the safety assist due to additional technology being added (*Euro NCAP | SEAT Leon*, no date). The report comments on the level of protection for knees and femurs of occupants of different sizes being indicated as good. It also mentions high deformation in certain areas of the car resulting in a penalty. The protection for the driver and passenger was stated as good or adequate for the side barrier test, the full-width rigid wall test and the side pole impact test (*Euro NCAP | SEAT Leon*, no date).

Relevant TCR Regulations

According to the TCR technical regulations, the Seat Leon is required to have a multi-point welded steel roll cage with protective padding attached to the cage ('2026_TCR_Tech_Regulations.pdf', 2026). A roll cage is used to protect occupants from being injured or killed in an accident, primarily during a roll over (Safiuddeen *et al.*, 2021).

The car is required to have FIA homologated racing seats and safety harnesses rather than the standard 3-point seat belt ('253_2024.pdf', 2024). These must both have reinforced mounting points following the guidance in the regulations. The mounts need to withstand significant loads as stated in the regulations. The seat requirements are designed to help manage spinal loads, reduce lateral movement and resist rearward collapse. The safety harness requirements are intended to help with frontal impact survivability.

Another requirement the car need to meet, is the fuel system protection. This includes fuel lines needing to be protected externally, to protect from deterioration from weathering and corrosion, and internal protection from deterioration and risk of fires. The tank also requires a leak-proof cover made from a non-flammable material ('253_2024.pdf', 2024).

TCR regulations require as much of the original shell to remain unmodified, however some areas may be modified. This includes reinforcement plates and controlled areas of modification, such as openings in the engine bay bonnet and removal of door soundproofing and decorative strips ('2026_TCR_Tech_Regulations.pdf', no date).

Modified Seat Leon

In order to make the Seat Leon race worthy, it has been modified in several ways. One modification the car has is a FIA Specification Roll Over Protection System (ROPS) with FIA regulation mountings, including reinforcement footplates to help distribute the load of the roll cage. This is necessary as a roll cage is required by the regulations as stated above.

Another modification to the Leon is additional bracing around front suspension turrets. This is typically used to improve performance by increasing stability and handling by decreasing chassis flex, through a better distribution of forces, during dynamic movements such as cornering (MANSOR *et al.*, 2024).

A further modification to the car is a FIA homologated racing seat and safety harness with reinforced seat mounting locations and reinforced harness mounting locations. These are required by the FIA regulations in order to race, as mentioned previously.

Additionally, the inner skin material in areas such as fuel tank, front inner arches, etc have been removed. The aim of this is to reduce the weight of the car to further improve the overall performance of the car.

Solid engine/transmission mounts to remove compliance

Triangulation between front suspension turrets and ROPS for additional forward crash safety

Air jack system with reinforcement around jack mounts

Analysis

Through the use of a roll cage, the Seat Leon would be considerably less safe for road use as it poses a threat to both the driver of the vehicle and other road users. There are several reasons for this, the first is that there is an increased head injury risk. A roll cage can interfere with airbags, possibly requiring them to be disabled. However, this risk is minimised through the use of a helmet and a harness, which as discussed earlier is already implemented in the car. The second issue with the roll cage is due to a reduction in crash energy absorption. Road cars are designed to deform in order to protect the occupants. By introducing a roll cage, it can potentially bypass intentional deformation paths and increase deceleration loads leading to a higher injury risk. Similarly to the previous issue, this can be mitigated through the use of helmets, harnesses and racing seats that are already implemented in the car.

However, the final reason why a roll cage may not be safe for use in a road vehicle, is due to road crash environments differ significantly to race crash environments. For example, road crashes can often involve trees or poles, pedestrians, offset impacts and multiple direction impacts.

On the other hand, the use of the roll cage is necessary for both occupant protection and crashworthiness within motorsport applications.

A potential improvement for the roll cage could be the material that is used. For example, typically a steel roll cage is used, however, other materials could potentially be better such as carbon fibre due to the impact force and its factor of safety in comparison to a standard steel roll cage (MANSOR *et al.*, 2024).

The use of a racing seat and harness is beneficial for occupant protection in both road and racing applications. This is because they hold driver in place and distribute crash forces across body which helps to reduce the risk of injury. However, road cars need to consider both comfort and cost, hence why current cars do not come with these as standard.

Another modification to the Seat Leon that may affect the crashworthiness of the vehicle is the removal of the inner skin material in areas such as fuel tank, front inner arches, etc. This could affect the areas that are designed to intentionally deform due to removing material that can absorb the kinetic energy in a crash. However, as the car has a roll cage installed, the roll cage should be able to compensate for this issue.

Conclusion and Further Work

In conclusion, in terms of crashworthiness the modified Seat Leon is suitable for TCR applications. However, as a road car it poses a potential threat to other road users and has removed some safety features that may be useful in a road crash. In terms of occupant protection, the modified Seat Leon is appropriate for TCR applications. Additionally, as a road car it is also suitable assuming the added safety features are used correctly.

In terms of further work, an occupant safety simulation for the vehicle could be beneficial to affirm current safety features are effective and find any potential areas of improvement. This could be done using a software that finite element analysis, such as ANSYS. This would allow for analysis of the behaviour and characteristics of the materials and geometry used.

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