Informational Document

regarding Implications on the Technical Risk Evaluation of Vehicles with Lower Loadpath

RCAR Damageability Working Group

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Abstract

RCAR’s Structure Test significantly contributed to continuous improvements of passenger vehicles’ damageability and repairability over the last decades in terms of reduced claims costs and total costs of ownership. This was enhanced by the Bumper Test, that promotes interacting energy absorbing systems. In recent years more and more vehicles appeared to have secondary energy absorbers derived from pedestrian protection (pedpro) structures, sometimes reducing strength of the main absorbers. These subsystems might improve the RCAR Structure Test performance because they reduce intrusion. On the other side there is no counterpart for these structures in real life car-to-car collisions and thus there might be even more intrusion than without such subsystems.

This document is based on research conducted by RCAR institutes worldwide and addresses the risk of lower pload paths.

It was found that there is no homogenous picture for the effects of lower load paths. This is due to the fact that the structural layout is different over brands and models. The results are mainly derived by lab tests that indicate additional damage where the lower load path is protruding the main load path and thus unnecessary parts are involved in front crash repairs. It was also found that the secondary load path can have an influence on the engine cradle, thus in real life calculations possibly resulting in replacement of parts that would not be affected without the lower load path.
1. **Introduction**

RCAR provides an international forum for members to exchange information on research findings and strategies for implementation. RCAR issues policy statements, design guides, position papers and other information for use by those involved in designing, constructing, repairing and insuring motor vehicles. This research is then used as a starting point to enter into a meaningful dialogue with vehicle manufacturers and others about putting that research to practical use.

2. **Background**

The RCAR Damageability Working Group addresses low speed crashes where, typically, no bodily injury of the occupants should occur in contrast to published consumer tests, e.g. New Car Assessment Programmes (NCAP), which mainly address a higher level of impact speeds.

For this purpose the RCAR Damageability working group has established standards for evaluating the damageability of vehicles in low-speed crashes in order to standardize the method of analysis of repair costs to promote performance improvements in low-speed crashes worldwide. The group also wants to provide the vehicle manufacturers with a tried-and-tested measure to facilitate the design of easily repairable vehicles.

While the group defines test procedures, it does not define rating methods for the test's results. These methods may be chosen according to local market-specific circumstances e.g. legal, technical, insurance coverage-related etc.

In the late 1980s a low speed test for the evaluation of structural damages and repairs was launched and since then has been used in several markets around the world: the RCAR Structure Test.

The RCAR Structure Test is a proven method to evaluate the capability of a vehicle to absorb impact energy in a severe city crash and support a cheap and easy repair. Today the Structure Test is the basic level where most vehicles are able to prevent their structure, e.g. side rails and subframes, from damage in such cases. It is this performance that ensures that city crash related damages can be repaired without welding and thus do not affect expensive and elaborate parts of the structure, such as high-strength-steel or cast body elements. By these means automakers have achieved and can verify the potential for an affordable cost-of-ownership of their product.

The ECE requirements for pedestrian protection led to the development of lower bars or stiffeners that are intended to push away a pedestrian’s lower leg in order to reduce knee bending moments accordingly. These stiffeners have been further developed to secondary crash structures by some automakers, partially with crashboxes and significant energy absorbance capacities. These secondary load paths are typically around 28 cm above ground and thus beneath the main crash management system. In this document the secondary load path will consequently be addressed as “lower load path” (LLP). The main argument from OEMs for the LLP
given in discussions is that this improves high speed crash performance, such as NCAP tests.

The RCAR Structure Test provides an infinite barrier from ground to a height above the vehicle’s front structures. Different from real life cars, the barrier will support any crash structure, may it be very high or very low, or may it be secondary. While RCAR addressed the problem of geometric compatibility with the Bumper Test, achieving a fairly good interaction of conventional crash management systems, there is no counterpart in real life for secondary structures. Thus the support by a LLP might improve the performance of a crash management system against the barrier, resulting in a good insurance rating. However, in real life crashes there will be no support for the main load path and the intrusion can exceed the test, resulting in higher claims costs than predicted.

Therefore the RCAR Damageability WG analyzed the issue and points out some key facts in the document.

3. Technical Background

The lower loadpath is can have different appearances with different effects. The following pictures demonstrate the differences. A ECE-compliant design is used by e.g. Volkswagen, where the lower stiffener is attached to the main crossmember and will not absorb significant energy. This design still loads the main load path and there is actually no second loadpath.

Fig. 1: Pedestrian protection system without additional support – no second loadpath, lower stiffener/pedpro device attached to crash boxes of standard crashmanagement system

Fig. 2: Pedestrian protection system without additional support – no second loadpath, lower stiffener/pedpro device formed by engine bay cover supporting bumper fascia (cut out)

Where there is a lower loadpath it will typically be bolted to the engine cradle that transfers the energy via it’s rear support into the cars lower body parts. The lower
load path may end before or after the main loadpath. Figure 3 shows a LLP with a protruding pedestrian protection element made of plastic, ensuring that there is only limited energy transfer in minor crashes due to breaking plastic, but in severe crashes the LLP might engage in order to limit deeper intrusions.

Fig. 3: Lower load path (yellow strut) not protruding main load path, pedestrian protection element (green) made of plastic, engine cradle not shown (source: OEM)

A dedicated LLP is shown in figure 4, where a protruding lower crossmember is supported by a strong longitudinal, again transferring the energy into the engine cradle. A special representative of this layout is shown in Fig. 5. This LLP doesn't even have a crossmember, but protrusions angled 10° outwards. Note that the RCAR Structure Test barrier is angled 10°.

Fig. 4: Lower load path protruding main load path, dedicated crashboxes and crossmember, engine cradle not shown (source: OEM)

Fig. 5: Lower load path not protruding main load path, protrusions without crossmember, engine cradle not shown (source: internet)
Several RCAR institutes tested such vehicles, Allianz Center for Technology AZT did comparative testing with a modified barrier. The results are inhomogenous, but allow conclusions for insurance technical risk evaluation.

4. Evaluation of the lower load path, lab tests

In crash tests and additional research on claims and insurance data the group reviewed the effects of lower load path designs according to their local requirements and market specific needs. In the following the institutes present their findings.

3.1. Germany

The German insurance group rating system evaluates newly launched vehicles using the RCAR Structure Test, which provides the data base for a rating proposal. The system also includes an annual statistical analysis of the claims costs and the model ratings are adapted annually. For dysfunctional crash management systems a significant change of rating resulting in increasing premiums for the customer might result from poor performance in the field. A detailed description of the German rating procedure is available on RCAR’s website.

Technical research

Allianz Center for Technology AZT found that some vehicles changed their group rating after the initial rating that had strong secondary structures. Some of these vehicles underwent comparative testing. The Ford Ka jumped up by 4 groups after the initial rating and indicated a 40% higher technical risk than expected. The Ka showed a dedicated, strong and protruding LLP (Fig. 6).

![Fig. 6: Ford Ka Crash management system with strong lower load path and protruding lower crossmember](image)

The Fiat 500 shares structure and crashmangement system with the Ford Ka. Both cars have been crashed, one of them under standard conditions, the other one with a raised barrier that did not interact with the LLP. The barrier was lifted 5 cm above the height of the LLP in order to avoid interaction or squeezing effects with the bumper fascia (Fig. 7).
Fig. 7: Raised barrier, dimensions

Fig. 8: Raised barrier (inverted RCAR rear impact barrier)

Fig. 9: Fiat 500, standard RCAR Structure Test 15.4 km/h

Fig. 10: both crashboxes compressed

The test setup is shown in Fig. 9 and Fig. 11, respectively. The test results differed significantly, as shown in the next figures. While the Fiat 500 shows similar compression of both crashboxes, with the main crashbox at its limits, the Ford Ka against raised barrier could not absorb energy in the LLP and exceeded the potential of the main crashbox. Deformation includes the side member, wing support, and other essential parts including both belt pretensioners.
The following table points out major differences in repair:

<table>
<thead>
<tr>
<th>Fiat 500, standard barrier</th>
<th>Ford Ka, raised barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire crashbox deformed</td>
<td>Crashbox fully compressed</td>
</tr>
<tr>
<td>Sidemember front plate repaired</td>
<td>Sidemember buckled and replaced (welding)</td>
</tr>
<tr>
<td>Lower crashbox used up to a large extend</td>
<td>Lower bumper damaged (by fascia) but unloaded</td>
</tr>
<tr>
<td>A/C condenser replaced</td>
<td>A/C condenser replaced</td>
</tr>
<tr>
<td>Left front wing tip repaired</td>
<td>Radiator support frame replaced</td>
</tr>
<tr>
<td>Strut supporting lower bumper replaced</td>
<td>Left wing destroyed</td>
</tr>
<tr>
<td></td>
<td>Wing mounting and bracket repaired</td>
</tr>
<tr>
<td></td>
<td>Strut supporting lower bumper replaced</td>
</tr>
<tr>
<td></td>
<td>front belts and tensioners replaced</td>
</tr>
<tr>
<td></td>
<td>B-pillar (passenger belt) repaired</td>
</tr>
<tr>
<td></td>
<td>Bonnet replaced</td>
</tr>
<tr>
<td></td>
<td>+ 2.025 € repair costs (+82 %)</td>
</tr>
</tbody>
</table>
Even the measured deceleration underlined the differing results, unveiling an additional intrusion of 76 mm with raised barrier and all forces applied to the main load path only. Curves show weak characteristics for the main load path alone.

![Deceleration Curves](image1.png)

**Fig. 15:** Comparison of deceleration curves, blue: main load path only (raised barrier)

After these impressive results further cars have been tested with both barriers. The Nissan Pixo showed a strong lower crossmember with crashboxes, but no strut. The supporting structure was formed by a massive front frame attached to the main side members. The car did not show different results in the tests, mainly due to the fact that the main crashbox showed significant reserves and had not been fully compressed by the raised barrier. Still the intrusion was increased: dynamic deformation during test was 125 mm with standard barrier vs. 140 mm with raised barrier.

![Nissan Pixo with protruding LLP](image2.png) ![After crash with raised barrier, crashbox not fully compressed](image3.png)

**Fig. 16:** Nissan Pixo with protruding LLP  **Fig. 17:** after crash with raised barrier, crashbox not fully compressed
It was obvious that the main crash management system of the Nissan Pixo was not weakened due to the presence of the secondary structure and thus could cope with real life requirements. Repair costs were similar for both tests.

Some cars were found by the institutes that have special protrusions (Fig. 5), actually representing secondary crashboxes without crossmembers. The test result of a car with such protrusions is shown in the following pictures. Dynamic deformation during test was 145 mm with standard barrier vs. 205 mm with raised barrier.

![Fig. 18: Alfa Romeo Giulietta with outriggers after crash with standard barrier](image1)

![Fig. 19: Alfa Romeo Giulietta with outriggers after crash with raised barrier](image2)

![Fig. 20: Alfa Romeo Giulietta, outriggers after tests (lower part = raised barrier)](image3)

![Fig. 21: Alfa Romeo Giulietta, crash boxes after tests (lower part = raised barrier)](image4)

The difference in dynamic deformation seems to be negligible, however, the crashbox is obviously at its limits and would not be able to absorb more energy. Even this small amount of additional intrusion led to 479 € additional repair costs (+11%).

Another test experience with the standard barrier has to be mentioned, where the LLP transferred energy into the engine cradle, which was shifted in its mounts. Since there was no information how to evaluate damage to the engine cradle, this could lead to a prophylactic replacement of the engine cradle. Even if the loss adjuster would decide to keep the cradle, additional wheel alignment work would be necessary in this situation. In this case the presence of the LLP is a disadvantage.
already in standard tests. The modified test showed additional intrusion of 40 mm (240 mm vs. 200 mm) and ignited belt pretensioners. Repair costs raised by 51% (2.122 €) after the crash with raised barrier.

Fig. 22: Opel Mokka (Chevrolet Trax) after standard test

Fig. 23: Opel Mokka after modified test

Fig. 24: Opel Mokka after standard test, both cashboxes compressed

Fig. 25: Opel Mokka after modified test

Fig. 26: rear engine cradle fixation after standard test - LLP displaced cradle

Fig. 27: Crash boxes after tests, L/H with raised barrier
The non-protruding LLP was also evaluated by testing the Opel Adam with a weak frontend of the LLP (Fig. 3, Fig. 28). This car has a dedicated LLP that is not protruding the main load path. It ends at the height of the crash box flange and only engages where intrusion exceeds the main crash management system’s capacities. Consequently the lower plastic stiffener broke away in both crashes (Fig. 29), because the displaced bumper fascia bent the stiffener in the modified crash. Minor additional damage occurred in the modified crash, resulting in additional repair costs of 161 €. Due to the repair friendly design and thus generally low repair costs, this small add-on represents a surplus of 8%.

Summary of AZT research

The results of the tests indicate an overall disadvantage for vehicles with lower load pathes. However, care has to be taken when evaluating this type of structure or crash management system. Not all LLPs indicate a higher technical risk for an insurer. However, especially the protruding lower structures have a potential for negative influences on repair costs and thus insurance premium. Even in these designs there can remain strong main structures that can cope with real life loadings. However, with todays dense engine bays, the inevitable additional intrusion wil very likely end up with higher repair costs compared to the RCAR test results.

Where the LLP is protruding and engaging in real life crashes, secondary effects like displacement of the engine cradle or damage to the LLP itself can increase costs even in low speed crashes. Non-engaging LLPs are typically affected by the deformed bumper fascia in a collision and at least parts of it will have to be replaced after low speed collisions. This is another reason for potentially higher repair costs for vehicles with LLP. The adjustment of restraint ignition criteria seems also to be affected by the interaction of the secondary load path, since twice belt tensioners fired where the realistic situation – no interaction of the LLP with a barrier – was tested.
It is obvious that LLPs ending behind the main crash management system have the best potential to reduce costs and could still provide protective potential in high speed crashes.

Since the design of LLPs shows very different characteristics and there is no simple indicator for the presence and the kind of LLPs, it was not possible to statistically evaluate the effects of the LLP on claims costs. Thus AZT’s research was restricted to lab tests.

3.2. Japan

JKC exemplified the LLP issue with an example. A Nissan March K13 was crashed according to RCAR standard and with a raised barrier (300 mm). Repair costs were compared and the influence on the insurance risk rating calculated.

The test with raised barrier unveiled deficits in the main crash management system, which led to a damaged side member. Thus repair costs increased by 26%. The additional intrusion was +15 mm.

Since the front crash is weighted 10.7% only, the final influence on the rating is not more than 4% in this case. Hence the conclusion for the Japanese market is that the LLP has no significant influence on the evaluation of technical insurance risk.
3.3. Korea

Korean Insurance group rating system evaluates newly launched vehicles with the results of the RCAR Structure Test and Bumper Test. The rating is quarterly updated in accordance with part prices and annually updated based on insurance loss ratio.

5 of 60 domestic vehicles which are newly launched since 2010 have LLPs. LLPs of the 5 cars could absorb energy in the structure test, so it might reduce intrusions and parts damage. However there was no significant performance advantage comparing to cars without LLPs. The following table shows major parts damages of the 5 cars with LLPs and damage rates of 55 cars with LLPs.

<table>
<thead>
<tr>
<th>Parts</th>
<th>Model A</th>
<th>Model B</th>
<th>Model C</th>
<th>Model D</th>
<th>Model E</th>
<th>Damage rate of 55 models w/o LLPs</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/C condenser</td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>X</td>
<td>25%</td>
</tr>
<tr>
<td>Radiator</td>
<td>-</td>
<td></td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>18%</td>
</tr>
<tr>
<td>Left sidemember</td>
<td>-</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>91%</td>
</tr>
</tbody>
</table>

x : damaged (replace or repair); - : not damaged

For the group rating, 4 of the 5 cars belong to rating classes worse than market average. However, due to the small number of cars with LLPs this does not necessarily indicate that the rating classes of the cars with LLPs tend to be generally included in the worse classes. In real life claims, there was no advantage or disadvantage data found regarding LLPs.

3.4. UK

Thatcham re-evaluated the repair costs found in Germany in AZT lab tests. Although figures differed due to different parts prices and labour costs. Still there was the same tendency towards a disadvantage for the vehicles with LLPs.

![Fig. 33: UK repair costs for Opel Mokka (Chevrolet Trax) Real-world Parts and Costs Analysis](image-url)
Real life data

For the cars under research in the AZT study, Thatcham evaluated real life claims data from an ABI data set, where the damaged parts were compared between test and real life repairs respectively repair calculations. There was no significance for a disadvantage in real life claims found. However, the comparison quality was limited due to the unsharp identification of affected parts in real life data, e.g. different parts names, unclear definition of damaged parts. Again the small number of vehicles available for the investigation limits the results.

3.5. SPAIN

Since January 2009 the Spanish insurance group rating system is based on the results of both the RCAR low speed structural crash test and the RCAR Bumper Tests. In the course of these tests CesviMap identified a group of cars with LLPs (“engine cradle”) and could compare them with a group of cars having only pedestrian protection crossmembers without struts transferring energy into the engine cradle (“cross member”, Fig. 1).

For the compared vehicles repair costs have been investigated and the resulting insurance group rating was rated. The following pictures indicate parts costs, labour costs, paint and overall rating.

Fig. 34: Labour costs for both groups, no significant difference
Fig. 35: Parts and paint costs for both groups, higher costs for vehicles with LLP.

Fig. 36: Overall costs for both groups, higher costs for vehicles with LLP.

Fig. 37: Insurance group rating for both groups, worse ratings for vehicles with LLP.
The test results indicate disadvantages in repair costs for vehicles with LLPs, also reflected in the group rating. Again the number of data is not significant. Furthermore there are two cars that stand out and thus might distort the result, it’s the Toyota RAV 4 with LLP and high repair costs as well as the Seat Mii without LLP and very low repair costs. To control for this effect, averages without these two cars were calculated:

<table>
<thead>
<tr>
<th>Average values</th>
<th>PARTS COST</th>
<th>BODY LABOUR COST</th>
<th>MECHANIC LABOUR COST</th>
<th>PAINT LABOUR COST</th>
<th>GD. TOTAL REPAIR COST</th>
<th>RATING</th>
</tr>
</thead>
<tbody>
<tr>
<td>LLP</td>
<td>2.240 €</td>
<td>351 €</td>
<td>7 €</td>
<td>318 €</td>
<td>3.135 €</td>
<td>29</td>
</tr>
<tr>
<td>No LLP</td>
<td>1.577 €</td>
<td>454 €</td>
<td>83 €</td>
<td>274 €</td>
<td>2.551 €</td>
<td>25</td>
</tr>
<tr>
<td>Relation</td>
<td>142%</td>
<td>77%</td>
<td>8%</td>
<td>116%</td>
<td>123%</td>
<td>+2</td>
</tr>
</tbody>
</table>

Still there is a visible disadvantage for those vehicles with a LLP, Obviously the parts costs mainly drive the repair expenses for this group. The insurance risk rating now differs only by two groups. This, however, still indicates higher insurance premium for the owner of a car with LLP in Spain.
5. Summary and Conclusion

Already in a former informational document on the benefits of the RCAR Bumper Test, technical research found less damage for crashes with well interacting crash management systems. This is directly related to the cost–of-ownership, either because insurance premiums may be lower or because vehicle owners have to pay less in cases without insurance coverage.

Vehicles with secondary or lower load paths can have weaker main load paths and the intrusion in collisions where no interaction of the lower load path is effective, will be typically higher, according to findings described in this paper. With this increased intrusion and the dense package in todays engine bays, it is very likely that vehicles with LLP suffer more damage in real life than under test conditions, where strong and protruding LLPs absorb a part of the impact energy and reduce intrusions. Thus the technical risk evaluation for motor insurance can be undermined.

However, the capability of the lower load path to absorb an impact and the performance of the main load path can widely vary over different designs. In general it can be concluded from the research, that protruding LLPs are likely to have negative effects on real life crash performance. LLPs that end behind the main load path can protect a car’s integrity in high speed crashes, but will not interact in low speed crashes and thus avoid the disadvantages of additional parts involved or other unnecessary damage in every day crashes.

While lab tests clearly show disadvantages for cars with LLPs, it was not possible to derive significant real life information from statistical data. However, with todays knowledge there is indication that the average influence of a lower load path on real life claims costs is not high enough to justify a change of the RCAR Structure Test criteria. The RCAR Damageability working group therefore decided to finish the topic with this presentation of the test results in order to provide information for OEMs and insurers on the specific issues found for varying types of lower load paths.

This conclusion of the RCAR Damageability WG shall not hide the fact that in individual cases with strong and protruding LLPs the technical risk might well be affected by the secondary structure and might also be decisive for insurance group rating results, where the front crash has a significant influence on the insurance group rating.