An independent review of the market for suspension and chassis systems

October 2002
An independent review of the market for suspension and chassis systems - sample

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Chapter 1 Executive summary

The automotive suspension and chassis industry is highly complex, with different designs used and manufacturing arrangements in place around the world. There is a multitude of political labour issues affecting the industry, as well as the constant battle between the steel and aluminium lobbies to use one material or the other. Companies are also frequently refocusing on ‘core competencies’, resulting in a great deal of change for the industry.

The world of suspensions is vast, but this concise report aims to provide an overview of what is driving the industry from a technological standpoint as well as identifying the leading players and the markets in which they are succeeding.

The primary focus has been the European market, but we have aimed to highlight the significant differences between the European, North American and the developing countries’ industries.

All vehicles need a suspension system to ensure that they provide their passengers with a smooth ride and that the vehicles themselves remain controllable and are not affected by bumps in the road. However, the nearest the average consumer gets to the suspension is when he or she changes a wheel and catches sight of the mechanics within the wheel arch.

Suspension systems have gradually developed over the past 100 years, from a rudimentary (and bone-shaking) system to the modern equivalent that allows vehicles to carry passengers at 70-80mph over great distances - safely and with little driver fatigue.

Electronics have played a major part in vehicle suspension systems for many years, but those electronics have also evolved - to the point where the suspension system's shock absorption ability and its springing can now be computer-controlled. Up-market vehicles such as the Mercedes-Benz S-class, BMW X7 and Volkswagen’s Phaeton and Touareg are beginning to use air suspension, whereby the vehicle is suspended on computer-controlled columns of gas or oil, rather than coil springs.

Away from the luxury market, the lower-end sector is also undergoing some change, improving vehicle packaging, handling and ride as well as emissions and cost. New materials are coming into play - high strength steels for the springs and anti-roll bars and aluminium for the suspension elements.

But it is not just the materials that are changing - new manufacturing processes are also emerging, such as cold forming for springs and hydroforming for suspension members. Less than 15 years ago, almost
Chapter 2 Introduction

A definition of suspension designs on European cars

The MacPherson Strut has been almost universally adopted for front suspensions in mass market (A, B, C and D segments in Europe, subcompact and mid-size in the US) cars around the world. This simple, cost-effective design uses a concentric coil spring/shock absorber strut together with a lower wishbone, or A-arm, to suspend the wheel. The name itself is taken from the Ford engineer that invented the system in the 1950s for use on Ford cars.

Figure 1 Macpherson strut

![Diagram of Macpherson strut](source: Industry sources)

The lower wishbone can either be a single A-shaped arm or split into two separate, ball-jointed links for greater control and weight reduction, such as the system used in the latest C-class model from Mercedes-Benz. The separate link concept used with MacPherson struts now allows superior suspension control for upper segment vehicles whilst at the same time being less expensive and more space-efficient than the traditional double wishbone system.
### Table 1 Examples of vehicle segments

<table>
<thead>
<tr>
<th>Segment</th>
<th>Region</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Europe</td>
<td>Ford Ka</td>
</tr>
<tr>
<td>B</td>
<td>Europe</td>
<td>Ford Fiesta, Peugeot 206</td>
</tr>
<tr>
<td>C</td>
<td>Europe</td>
<td>Peugeot 307, Ford Focus, Volkswagen Golf</td>
</tr>
<tr>
<td>D</td>
<td>Europe</td>
<td>Ford Mondeo, Opel Vectra, Nissan Primera</td>
</tr>
<tr>
<td>E</td>
<td>Europe</td>
<td>BMW 5 series, Mercedes-Benz E-class, Audi A6</td>
</tr>
<tr>
<td>Sub-compact</td>
<td>North America</td>
<td>Hyundai Elantra</td>
</tr>
<tr>
<td>Mid-size</td>
<td>North America</td>
<td>Honda Accord, Toyota Camry, Ford Taurus</td>
</tr>
<tr>
<td>Full-size</td>
<td>North America</td>
<td>Lincoln Town Car</td>
</tr>
</tbody>
</table>

Source: just-auto.com

Four-wheel-drive vehicles have traditionally used rigid, ‘live’ front and rear axles, suspended by multiple bar links to provide high strength and sufficient wheel articulation. The emergence of the sports-utility vehicle (SUV) has seen a major switch to independent suspension systems in order to provide the car-like handling that consumers now expect (although it also comes with the loss of some off-road ability). These have been developed to such an extent that models such as the BMW X5 and Mercedes-Benz M-class now use MacPherson strut, double wishbone and multi-link front and rear suspensions.

### Figure 2 BMW X5 suspension components

Source: BMW
Springs can take many forms:

- **Coils**
  Conventional, used in the majority of applications.

- **Torsion bars**
  These spring steel rods provide a springing effect by resisting twisting forces from the wheel (or the arm that the wheel is mounted to).
  Torsion bars can directly replace coil springs at the wheel, unit by unit, or they can be bundled into a torsion 'beam', or axle, mounted transversely between the wheels (a torsion beam, or axle, mounted transversely between the wheels). Torsion bars have been the spring of choice in a whole generation of PSA Peugeot Citroën Group vehicles, ending only recently with the Citroën ZX and Peugeot 306 (torsion bars were used instead of coil springs at the rear). The Peugeot 307 uses a more conventional coil spring arrangement.
• **Leaf springs**
  Mounted longitudinally, these were used in earlier cars and were very common in commercial vehicles some years ago. They have now been completely replaced in modern European cars by coil springs. The Fiat Panda was one of the last European cars to use leaf springs. Leaf springs are still used in some heavier commercial vehicles, particularly for long wheelbase chassis cab conversions for instance.
• **Transverse leaf springs**

These are mounted across the vehicle between the two wheels and perform a locating as well as a springing function for the wheels. For this reason, they can help to save weight, space and cost because fewer wheel suspension components are needed. A fibreglass reinforced plastic transverse leaf spring was introduced in the Chevrolet Corvette a few generations ago and is now also used in DaimlerChrysler’s Smart city car.

• **Air springs**

These can take a number of different forms, from a simple airbag for self-levelling of a normal coil or leaf suspension, to fast-acting, computer-controlled active full air suspension systems (without the need for coil springs). A type of ‘airbag’ has been used for many years for self-leveling suspension in trucks; active air suspension systems have only recently begun to break into the upper luxury segment vehicles. Interestingly, this technology has developed from the airbags suspension spring medium used in the heavy truck industry.

**Anti-roll bars**

Anti-roll, or stabiliser, bars help to solve the problem resulting from the need for a car to have a smooth, fluid ride whilst also being capable of rapid changes of direction and fast cornering without excessive body roll. Anti-roll bars are typically formed from transversely fitted solid or tubular spring steel, typically having relatively small diameters, and are fitted transversely between the wheels of front-wheel drive cars that have to carry a heavy diesel engine (which makes body roll more of a problem) or sports cars. In many cases, the smallest-engined front-wheel drive vehicles are able to run without an anti-roll bar. Almost all executive and luxury vehicles now use them as standard - one each for the front and the rear axles.
Chapter 3 Major issues in the chassis and suspension industry:

Cost reduction

Vehicle manufacturers are under constant pressure to reduce costs - now more than ever. The events of September 11th 2001 saw a rapid fall in global consumer confidence - a fall that is only now starting to be remedied in most parts of the world.

On-going consolidation by the vehicle manufacturers in order to focus on core competencies has further added to the competitive burden. All the recently merged groups such as Daimler and Chrysler, GM and Fiat (powertrain division), and Renault and Nissan are examining ways to cut costs by component sharing. This includes engines, vehicle platforms, and many more components.

For example, GM and Fiat will be sharing suspension architecture for the first time on GM’s Epsilon platform (Vectra, Saab 9-3 and future Fiat, Alfa Romeo, and Lancia models) but with different tuning to reflect brand values. This will result in a significant cost saving in terms of suspension and chassis componentry. Fiat, until very recently, has tried to provide different suspension designs for different brands, despite the fact that the cars share a common platform (and despite the low production volumes, too).
Vehicle manufacturers are also switching to less expensive suspension designs wherever possible: both Honda and Mercedes-Benz (in the Civic and the C-class) have recently made this move to cut costs. Honda has switched to a twist beam rear suspension and MacPherson strut front suspension. The C-class has switched from double wishbone front suspension to an elaborate MacPherson strut design - purely a cost-cutting move. Even the new Range Rover has suffered at the hands of the accountants - its front steering knuckles were downgraded in specification and cost shortly after Ford inherited the programme from BMW.

**Weight reduction**

<table>
<thead>
<tr>
<th>Weight, the mass, that over the weight of a vehicle can be reduced</th>
<th>Save power front suspension for a 6.7kg weight saving.</th>
</tr>
</thead>
</table>
| Europe switching to the use of aluminium in its new MacPherson strut front suspension |}

**Figure 5 Saab 9-3**

Source: Saab
**Size reduction**

Double wishbone suspensions are not very compact but offer the prospect of good vehicle dynamics. Honda recently switched to MacPherson front strut suspension to liberate under-bonnet space as well as cut costs. The Mercedes-Benz C-class and Audi A4 have also both switched to MacPherson strut front suspension designs.

**Improved vehicle handling**

There is pressure on the vehicle manufacturers to offer ‘unique selling points’ in today’s highly competent car market. Ford took a gamble with the Focus by equipping it with a fully independent “Control Blade” rear suspension at great cost. However, it is effectively the only mass-produced medium-sized hatchback on the market with independent rear suspension and has since achieved a formidable reputation for handling. Multi-link suspensions, such as the pseudo but effective solution on the rear of the Focus, can offer greatly improved handling over the cheaper, conventional twist beam rear. Volkswagen is so worried by the Focus being able to steal its Golf GTi handling crown that the next Golf, the Mk V, will also use an independent rear suspension when it is launched at the end of this year.

![Figure 6 Golf Mk5](image)

*Source: Volkswagen*

**The two-tier market (with growth in the medium cost bracket)**
Chapter 4 Market review

Global market

The global suspension systems market is estimated by just-auto.com to be worth around US$16 billion. This does not take into account the split between in-house and outsourced systems. Of the global market, the European market is estimated to place more multi-link and air suspensions elsewhere in the world. The biggest market is probably held by BMW, Mercedes-Benz, the Volkswagen Group, GM-Opel and Ford. The ZF Group, arguably one of the largest chassis and suspension system suppliers, generated 65% of its 2001 global sales in Europe.

<table>
<thead>
<tr>
<th>Chassis module supplier</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ArvinMeritor</td>
<td>Just breaking into the market - starting with commercial vehicles.</td>
</tr>
<tr>
<td>Benteler Automotive</td>
<td>Significant business with Ford and ZF.</td>
</tr>
<tr>
<td>BV Chassis systems</td>
<td>Supplies Saturn’s Vue and Cadillac CTS rear suspension module.</td>
</tr>
<tr>
<td>Delphi</td>
<td>Significant corner module and axle module assembly business in Europe.</td>
</tr>
<tr>
<td>Tower Automotive</td>
<td>Supplies front corner modules to Cadillac CTS. Little business in Europe.</td>
</tr>
<tr>
<td>ThyssenKrupp Automotive</td>
<td>Assembles all Porsche axle/suspensions but still relatively small player. Has plans in place to become world leader.</td>
</tr>
</tbody>
</table>

Source: just-auto.com

It is very difficult to compare market shares of the various companies that are involved with the production of suspension and chassis systems. This is because no two suppliers ever have the same definition of a module. The modules contain different numbers of components - making it a very different business to the supply of single components such as springs or anti-roll bars.
Table 3 Selected suspension component and chassis module (passenger car and LCV) global production volumes, by company, 2001

<table>
<thead>
<tr>
<th>Company</th>
<th>Product</th>
<th>Annual volume</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARA</td>
<td>Coil springs and anti-roll bars</td>
<td>N/A</td>
<td>World leader in anti-roll bars</td>
</tr>
<tr>
<td>Benteler</td>
<td>Chassis components: frames, suspension arms etc.</td>
<td>10 million</td>
<td>Supplies chassis modules using sourced springs etc.</td>
</tr>
<tr>
<td>ArvinMeritor</td>
<td>Suspension springs</td>
<td>10 million</td>
<td>Only in the US market</td>
</tr>
<tr>
<td>ArvinMeritor</td>
<td>Anti-roll bars</td>
<td>4.5 million</td>
<td>Only in European market (through purchase of UK’s Tempered Spring)</td>
</tr>
<tr>
<td>Mubea</td>
<td>Suspension springs and anti-roll bars</td>
<td>36 million</td>
<td>Growing fast with cold-formed high strength steel coil springs and bars</td>
</tr>
<tr>
<td>NHK Spring</td>
<td>Coil springs and anti-roll bars</td>
<td>N/A</td>
<td>Big player in Japan and the Far East</td>
</tr>
<tr>
<td>ThyssenKrupp Automotive</td>
<td>Coil springs</td>
<td>37 million</td>
<td>World’s largest automotive coil spring supplier</td>
</tr>
<tr>
<td>ThyssenKrupp Automotive</td>
<td>Anti-roll bars</td>
<td>N/A</td>
<td>World’s number 2 supplier</td>
</tr>
<tr>
<td>ZF</td>
<td>Suspension arms, ball joints, rubber mounts, anti-roll bar links, suspension and chassis modules</td>
<td>N/A</td>
<td>Main products are ball joints and anti-roll bar links, on which other business is dependent</td>
</tr>
</tbody>
</table>

Source: just-auto

**Delphi**

Delphi’s large market share can be attributed to its acting as suspension module integrator on many GM models (as well as other manufacturers’ vehicles, such as the new BMW Mini and Land Rover’s new Range Rover and Discovery). In this case, although Delphi does not manufacture all the suspension arms itself, it machines and integrates them into corner/strut modules. Many of Delphi’s modules are based on simple MacPherson struts with lower A-arms.
When comparing the different module specialists, it is far more useful to refer to their turnover - this gives a better idea of their standing in the automotive industry.

**ZF**

ZF, for instance, has a very high turnover in terms of chassis and suspension modules, especially in German-manufactured vehicles. It already assembles complete modules for both Mercedes-Benz and BMW (M-class, X5, Z3 and forthcoming X7) in the US. ZF has also recently introduced complete module assemblies for the German sedan and Crossout models and the upcoming common platform models. The ZF six-speed automatic transmission is now in the US because Ford has chosen to outsource almost the complete drivetrain.

When comparing ZF to other companies such as Benteler and ThyssenKrupp Automotive, it is important to bear in mind that the company is approaching its chassis task from a fundamental rubber-to-metal and linkage basis; the core businesses of its Lemförder subsidiary and recent Sachs acquisition.

ZF sources some components from Benteler, and points out that Benteler is developing into the chassis/suspension module business from a structural point of view, using metal tubing to form structural and suspension components. In fact, ZF usually buys its chassis subframes from Benteler.

ZF Lemförder Fahrwerktechnik’s (chassis technology) worldwide turnover in 2001 was €1.8 billion, which includes chassis componentry (such as suspension arms, axle modules and tie rods), rubber-to-metal mountings for suspension, engine and chassis as well as gearshift systems.

The company’s powertrain and suspension division, headed up under the ZF-Sachs name, made €2.1 billion in worldwide sales in 2001.

ZF North America, which supplies complete front and rear axles for Mercedes-Benz and BMW (M-class, X5, Z3 and forthcoming X7) in the US, also made US$1.8 billion in 2001 (part of the ZF Lemförder turnover listed above) and expects turnover of more than US$2 billion in 2002. It should be noted that this figure also includes ZF’s steering and industrial and commercial vehicle component supply operations. The company has also announced that it has won the contract to supply front and rear axles to the next generation Mercedes-Benz M-class (and for the segment-busting Vision GST six-seater wagon, with which it shares a chassis). It is adding 33% to the capacity of its Tuscaloosa, Alabama, facility in order to do so.
TRW estimate that MacPherson struts are used in A, B, C, D and E segments, representing around 81% of the market. Of that 81%, 85% of the lower A-arms that go with the strut arrangement are sheet metal pressings and the 15% that are aluminium or forged steel. Sheet metal front suspension arms cost an average US$13 per unit, so the 26 million unit European (Western and Eastern) market is worth around US$340 million. The five million unit market for forged steel and aluminium control arms is worth around US$75 million, at an average US$15 per arm, a 25% cost penalty over sheet metal arms.

Double wishbone front axles are used in segments C, D, E as well as in SUVs. These systems represent around 11% of the market. TRW supplies upper and lower wishbones as well as anti-roll bar links.

True multilink suspensions (not double wishbone) represent only 7% of the market and are used almost exclusively in the D and E segments. TRW point to the Mercedes-Benz C-class as being a good example of a modern multi-link front suspension installation. That vehicle’s front suspension is three-link with a MacPherson strut; two ball-jointed arms replacing the lower A-arm, and a third link provided by the steering arm.

TRW’s main customers are BMW, GM, Renault, Fiat, PSA and the Volkswagen Group. TRW also supplies some linkages to DaimlerChrysler and, to a lesser extent, to Honda.

The Italian market

The Italian motor industry is notoriously difficult to penetrate because the OEMs almost exclusively use Italian component suppliers. In view of this, ThyssenKrupp Automotive’s ongoing attempt to purchase Magneti Marelli’s suspension division (which supplies almost all of Fiat’s suspension needs) looks to be a shrewd move. Other non-Italian...
Chapter 5 Technology review

Vehicle manufacturers are increasingly looking towards using lightweight metals and new forming techniques (such as aluminium, magnesium and new steels) in order to reduce car weight. In the suspension department, reduced vehicle weight results in improved ride and handling.

Measures to reduce the ‘unsprung mass’, or parts of the car that are not sprung (wheels, tyres, brakes and suspension components) also benefit ride and handling. At the same time, the demands placed on the suspension continue to grow as the weight of new systems (such as air conditioning, diesel engines, hybrid battery packs and in-car multimedia) increase the overall weight of the vehicle. As an example, the 1.1 litre VW Polo weighed just 685kg in 1981; whereas the modern-day 1.0 litre VW Lupo (its rough equivalent for space) now weighs 912kg. Even the new ‘lightweight’ aluminium Audi A2 weighs 899kg in 1.4 litre form, which illustrates how the addition of equipment associated with crash protection has increased the overall weight of the average car over the past couple of decades.

Figure 7 Audi A2

New metal forming techniques

Manufacturers are now using new metal forming techniques such as thixo forming, squeeze casting and hydroforming. Hydroforming has been in mass production since BMW’s most recent 5-series, where it is used in the rear axle frame. The first two methods however, have yet to prove themselves in mass-produced suspension components, despite
The opposite side to the weight reduction argument is cost, as aluminium will always be more expensive than steel and cast iron. In addition to this, aluminium is not capable of producing the performance of steel or cast iron components in certain instances.

Cost cutting can even occur at the highest levels however; the new Range Rover was originally planned to use aluminium knuckles but these have now been changed to forged steel to reduce costs (and possibly also to improve handling and refinement).
Chapter 6 Tier 1 supplier profiles

American Axle Manufacturing (AAM)

This large US-based company produces prop shafts and axles for larger, more traditional vehicles (typically 1.8 tonnes and above). It does a significant amount of work for GM (85% of its business in 2000). Ford is also a customer.

The company recently won its first DaimlerChrysler business with the rear axle of the Mercedes-Benz six-tonne Sprinter. Rolls Royce and Bentley also use its axles (manufactured in the US) following the purchase of the Scottish Albion Automotive company.

Albion itself produces 4x4 axles for medium duty trucks (1.8-18 tonnes), including the 5.5-tonne Renault Messenger van and LDV lorries.

Albion’s respected axles are also in use on the new Range Rover and could also be fitted to the new Porsche Cayenne/Volkswagen Touareg SUV siblings, although this is not clear at the time of writing.

ArvinMeritor Suspension Systems

ArvinMeritor is not well-known for suspension or chassis components or systems, but its Light Vehicle Systems (LVS) division recently bought Tempered Spring, the UK-based global supplier of hot- and cold-formed anti-roll bars and valve springs. Tempered Spring at the time had roughly a 14% share of the European anti-roll bar market. The company’s major European customers were Ford, VW and Opel and BMW.

The American company supplies suspension components for the Mercedes-Benz Sprinter as well as the anti-roll bar and wheels for the European-built Chrysler Voyager.

The company is also investing in its European operations through its AP Amortiguadores joint venture with Kayaba, the shock absorber maker (even though the ArvinMeritor/Kayaba joint venture recently ended in the US). The European operation is focusing on the development of the complete corner module, including the strut, coil spring and anti-roll bar, which customers can then fine tune to their requirements using special design software.
Assembly capability requirements

On the subject of the supply of full engineering and assembly capability to the OEMs, ArvinMeritor says that module acceptance depends on the customer - and as a newcomer it is not always easy to win that business without a track record. However, they do point out that European and US customers generally expect a supplier to integrate sub-components (especially in the US). The module developer must have the expertise necessary to overcome some of the issues that a car maker might have if it developed the module.

One large piece of current European business for the company is the 100% fitment of Tempered Spring’s solid anti-roll bars on the Volkswagen Group’s new PQ24 (VW Polo, Skoda Fabia and Seat Ibiza) high volume platform.

Weight reduction

As for weight reduction, the company said that this is a requirement in both Europe and the US, and that aluminium and fabricated sheet steel are being explored for suspension arm applications as alternatives to the current cast iron or forged steel components. ArvinMeritor points out that it is still a little cautious with aluminium - its price is not quite as stable or as low as it perhaps ought to be in order to make it a true alternative.

New independent rear suspension

For the US, the company unveiled its new modular independent rear suspension at the 2001 Frankfurt motor show to prove to customers its ability to manage a team of diverse supplier partners and integrate a suspension from concept to prototype and on to production. The design is targeted for a full size US SUV or light truck.
Chapter 7 Specialist manufacturers and developers

Alcoa

The company produces a range of aluminium components for the car industry, including the current Audi A8 spaceframe, wheel and bumper beams. Though not a significant supplier of suspension/chassis components, the rear subframe produced for Volvo's S80, V70 and S60 models is significant, of which are estimated to be around 2,000. Likely future applications could include future models such as the Jaguar X350, which shares many components with the S80.

Algat

This Italian company is now a major Tier 2 supplier of suspension arms to Magneti Marelli's chassis division. Algat itself produces welded subframes.

Allevard Rejna Autosuspensions Group (ARA)

Allevard Rejna Autosuspensions Group (ARA) is jointly owned by NHK Spring of Japan and Magneti Marelli. Established on May 31st 2000, it is Europe's leading producer of suspension components (helical springs, anti-roll bars and torsion bars), and is owned by Sogefi, Italy's second largest components manufacturer behind Magneti Marelli.

ARA was formed through the merger of Sogefi's two existing suspension component makers, Rejna of Italy and Amsu of France, as well as Allevard Ressorts Automobile, which was bought in late 1999 from the Usinor group.

In 2000 sales revenues reached ITL734 million (€379.3 million), excluding revenues from United Springs that were consolidated as from fiscal year 2001. Sales in 2001 (including United Spring sales) reached €404.3 million.

Sogefi is active in this sector through the companies Rejna S.p.A. and Allevard Rejna Autosuspensions S.A. (ARA) for cars and through the companies SMB S.r.l., LPDN Gmbh and NAM S.A. in the heavy-duty vehicle sector.
Appendix 1 Lotus’ ULSAS project

In 1997, building upon the success of other Ultralight programmes, the International Iron and Steel Institute (IISI) commissioned the Ultralight Steel Auto Suspension (ULSAS) project. Collectively, these activities form part of a cohesive, global steel industry strategy of meeting environmental demand for fuel efficiency, through the development of mass-optimised and recyclable products and assisting the competitiveness of its customers, the vehicle manufacturers, through the provision of lightweight, cost-effective engineering solutions.