How can active suspension reduce cost in rail vehicles?
Rickard Persson, KTH Rail vehicles
## Examples of active suspensions today

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Application</th>
<th>Business case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shinkansen (Japan)</td>
<td>Active secondary lateral suspension to reduce aerodynamically induced vibrations.</td>
<td>The active suspension makes it possible to run at enhanced speed, which may attract more passengers and makes use of vehicle and crew more efficient.</td>
</tr>
<tr>
<td>X2000 (Sweden)</td>
<td>Active tilting to reduce lateral quasi-static acceleration</td>
<td></td>
</tr>
<tr>
<td>ETR1000 (Italy)</td>
<td>Active secondary lateral suspension to reduce vibrations at high speed curving</td>
<td></td>
</tr>
</tbody>
</table>
RUN2Rail in short

Budget: 2,732,463€

Partners: 15

Duration: 24 months

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RUN2Rail in short

WP1 - Innovative sensors & condition monitoring
WP2 - Optimised Materials and Manufacturing Technologies
WP3 - Active Suspension & Control Strategy
WP4 - Noise and Vibration
WP5 - Dissemination, Exploitation/Impact Management and Cooperation with Shift2Rail

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What is active suspension?
The actuator

There are many types of actuators, the most common type is similar to a conventional hydraulic damper.

1. If we make the damper controllable we get a semi-active actuator
2. If we want to have a fully active actuator we must add a power source, a pump driven by an electrical motor
# RUN2Rail WP3
## The new business case

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Application</th>
<th>Business case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single axle running gear for passenger vehicles</td>
<td>Active suspension to achieve an acceptable vibration comfort</td>
<td>Reduced vehicle weight</td>
</tr>
<tr>
<td></td>
<td>Active wheelset steering to reduce wear on wheel and rail</td>
<td>Reduced vehicle cost</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduced maintenance cost</td>
</tr>
</tbody>
</table>
## RUN2Rail WP3
### Target vehicle properties

<table>
<thead>
<tr>
<th>Key property</th>
<th>Metro Madrid class 8000</th>
<th>Innovative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max speed</td>
<td>120 km/h</td>
<td>120 km/h</td>
</tr>
<tr>
<td>Number of cars</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Train length</td>
<td>55.049 m</td>
<td>36.000 m</td>
</tr>
<tr>
<td>Pay load per m</td>
<td>1.000 kg/m</td>
<td>1.000 kg/m</td>
</tr>
<tr>
<td>Tare weight per m</td>
<td>1.900 kg/m</td>
<td>1.500 kg/m</td>
</tr>
<tr>
<td>Pay load to tare weight ratio</td>
<td>53%</td>
<td>67%</td>
</tr>
<tr>
<td>Max axle load at pay load</td>
<td>14.350 kg</td>
<td>15.000 kg</td>
</tr>
</tbody>
</table>

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The source for the weight savings

The axle boxes moved to inside the wheels

One suspension step eliminated
No need for air suspension
Anti roll bar part of frame
The weight savings on the running gear will lead to other weight savings (100 kg/m)

7530 kg
=> Shorter and lighter axle
=> More compact and lighter frame
=> Less weight
=> Cheaper + Air free train???
=> Less weight

3000 kg

In total 400 kg/m weight savings
A bogie has two suspension steps, one from wheelset to frame and one from frame to carbody. The single axle running gear has only one suspension step. A suspension step works like a filter, attenuating vibrations. As the vibrations initiate from the rail there is a risk that the vibration attenuation from rail to carbody might be poor.
The simulations confirm that the ride comfort with passive suspension will be unacceptable.

With active suspension the ride comfort will be acceptable.

Simulated vertical ride comfort on tracks with different qualities
Wikipedia: Excessive flange squeal on tight curves has been a problem on class 142 caused by the long wheelbase and lack of bogies.

Simulations for the innovative vehicle with passive axle guidance confirm that the wheel (and rail) wear will be worse than for the reference bogie vehicle.
## RUN2Rail WP3
### Wheelset steering

<table>
<thead>
<tr>
<th>Force wheelset to radial position</th>
<th>Motorized independently rotating wheels</th>
<th>Frequency dependent axle guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Diagram" /></td>
<td><img src="image2" alt="Diagram" /></td>
<td><img src="image3" alt="Diagram" /></td>
</tr>
</tbody>
</table>

- **Two longitudinal actuators force the wheelset to take a radial position**
- **The motors on the independently rotating wheels are controlled to make the wheelset to take a radial position**
- **The frequency dependent axle guidance will allow the wheelset to passively take an approximately radial position**
RUN2Rail WP3
Wheelset steering

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Passive bogie vehicle (reference vehicle)</th>
<th>Passive single axle running gear</th>
<th>Force wheelset to radial position</th>
<th>Motorized independently rotating wheels</th>
<th>Frequency dependent axle guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wear on wheel and rail relative to reference vehicle</td>
<td>0%</td>
<td>+45%</td>
<td>-71%</td>
<td>-94%</td>
<td>Not studied yet</td>
</tr>
</tbody>
</table>

Metro Madrid Line 10 as example for wear calculations

The calculation is made per axle
Conclusion

The single axle running gear will reduce the tare weight per meter train with 400 kg/m (40 tons for a 100 m long train)

40 tons less to manufacture

40 tons less to propel

With active suspension installed this vehicle will bring acceptable ride comfort and reduced wheel and rail wear