Reference training materials

G. Cebrat FGM
Contributions: Ivan Ivanov IVECOL

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2. Introduction

In D3.1, the draft implementation handbook, the curricula were described for the different target groups, the description focused on reasoning what type of content is suited for the training of the different target groups. D3.1 also features tips for organising and holding courses.

Here we present some handouts for the courses described in D3.1. Please note that the content given here does not comprise ready-to-use handouts. We expect you to adapt the content for the respective target groups and application. D3.1 gave some tips about the didactics - higher ranked staff is less willing to accept presentations or work on examples - be prepared to face reactance and use methods involving them for example by using the right headlines for the right target groups:

- Top management is interested in shareholder or stakeholder value
  - Motivation mainly in terms of money
- Middle management is interested in smooth and efficient operation
  - Motivation: smooth running gives them more time for strategic development
- Drivers are interested in reducing stress and accidents
  - Reduced health risks form a mayor benefit
  - Helpful driver cockpit helps in applying ecodriving
- Blue collar workers are interested in reducing stress and gaining recognition
  - Checklists and helpful working environments help mastering the work with a high quality
3. Disclaimer

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Although we do our best to give you the best available knowledge, we have to exclude any liabilities for events resulting out of this information.

RECODRIVE provides this information to improve knowledge about fuel saving in the transport sector. Our goal is to keep this information timely and accurate, but we accept no responsibility or liability whatsoever with regard to the information given herewith.

This information is:

- of a general nature only and is not intended to address the specific circumstances of any particular individual or entity;
- not necessarily comprehensive, complete, accurate or up to date.

Please consider the date of the published version and follow the pointers to get a deeper insight.
4. Elements of a Sustainable Fleet Management

This handout summarizes the most important facts for sustainable fleet management. It makes the approach transparent and enumerates the benefits. The target group of this handout is the management staff.

4.1. Motivation – Stakeholder or Shareholder Value

Depending on the type of organisation we may see different priorities:

For carriers in long distance, the fuel efficiency per transported goods is most important, for city-owned public transport, avoiding damage or loss of buses is the main danger.

<table>
<thead>
<tr>
<th>Company type</th>
<th>Service type</th>
<th>Focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-employed</td>
<td>Long haul truck</td>
<td>Main focus on fuel efficiency paired with flexibility for take-up of load</td>
</tr>
<tr>
<td>Self-employed</td>
<td>Parcel delivery</td>
<td>Main focus on handling efficiency, fuel costs second</td>
</tr>
<tr>
<td>Company</td>
<td>Long haul truck</td>
<td>Main focus on fuel efficiency</td>
</tr>
<tr>
<td>Public</td>
<td>Service/distribution</td>
<td>Main focus on handling efficiency, fuel costs second</td>
</tr>
<tr>
<td>Company</td>
<td>Parcel delivery/ utility</td>
<td>Main focus on indirect costs, fuel costs second</td>
</tr>
<tr>
<td>Public</td>
<td>Regional passenger transport</td>
<td>Main focus on indirect costs, fuel costs second</td>
</tr>
<tr>
<td>Company</td>
<td>Regional passenger transport</td>
<td>Main focus on indirect costs, fuel costs second</td>
</tr>
<tr>
<td>Company</td>
<td>Long distance passenger transport</td>
<td>Main focus on fuel efficiency</td>
</tr>
<tr>
<td>Self employed</td>
<td>Taxi services</td>
<td>Main focus on indirect costs, fuel costs second</td>
</tr>
<tr>
<td>Public</td>
<td>Official cars</td>
<td>Main focus on indirect costs, fuel costs second</td>
</tr>
<tr>
<td>Company</td>
<td>Company cars, executive cars</td>
<td>Main focus on indirect costs, fuel costs second</td>
</tr>
</tbody>
</table>

The analysis shows that with three types of business’ fuel efficiencies should be top-ranked. With others the ranking of the fuel efficiency depends on the wages for the drivers. It might be ranked first in low-wage countries. Since eco driving influences driving behaviour and safety, indirect costs are covered in almost the same manner reducing tail end crashes and manoeuvring mistakes.
But at large the RECODRIVE approach is dominated by improvements in management and quality:

**Figure 1 RECODRIVE approach**

The RECODRIVE approach is benefiting your company in the following way:

- You have a planned approach for improving the organisation, one that is driven by hard facts.
- Progress and results are clearly evident at low risk, so the organisation is more accountable and transparent to its stakeholders, thereby building ongoing loyalty and trust.
- Recognition is building on satisfaction and loyalty amongst employees reducing fluctuation.
- Customer satisfaction is retained, because it is part of the evaluation.
- The total cost of ownership approach allows concentrating resources on issues that matter.
- Formalised process improvements benefit the working efficiency and effectiveness when implementing other measures and make process chains shorter and more robust.
- The RECODRIVE label is a benefit for your public image.
- Benchmarking fuel efficiency externally further adds credibility.
Concluding RECODRIVE either directly improves the companies’ performance by reducing the total cost of ownership or indirectly raise the companies’ value by allowing to state environmental excellence.

This may be reflected in an Environmental and Social Report which summarises the attempts.

![Figure 2 Title Page Environmental and Social Report Oxford Bus Company](image)

**4.2. The overarching RECODRIVE approach**

The details differ for the different fleet types, but we see the following actions with the RECODRIVE approach:
Figure 3 Elements of a sustainable fleet management

Integrated fleet planning not only targets the optimisation in the status quo, but also asks questions about most efficient service fulfilling including vehicle operation and logistics. The type of operation leads to different focuses of the measures:
Table 2 Pre-drive focus for city, regional, long distance operation

<table>
<thead>
<tr>
<th>Operation Focus</th>
<th>City</th>
<th>Regional</th>
<th>Long Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tour-related</td>
<td>Optimise logistics</td>
<td>Pre-planned milk run</td>
<td>On demand freight exchange</td>
</tr>
<tr>
<td>Vehicle type</td>
<td>Hybrid electric?</td>
<td>Intermediate</td>
<td>High efficiency at the most frequent operation point</td>
</tr>
<tr>
<td>Vehicle choice</td>
<td>Exchange or trailer?</td>
<td>If possible</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

If we differentiate between passenger and freight transport, we may find the following measures for the different types of operation:

<table>
<thead>
<tr>
<th>Operation Focus</th>
<th>City</th>
<th>Regional</th>
<th>Long Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main focus freight</td>
<td>Flexibility of rolling material usage and regeneration of braking energy, avoiding idling</td>
<td>Routing</td>
<td>Optimised single point efficiency</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Multi functional vehicles</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Adaptation of power train to the topography</td>
</tr>
<tr>
<td>Main focus passenger transport</td>
<td>Same</td>
<td>Adaptation of power train to the topography</td>
<td>OSPE + Low consumption comfort devices</td>
</tr>
</tbody>
</table>
Touching all those issues may result in achieving ISO14001 and EMAS accreditations more easily. The steps are:

- Obtain commitment at the Directorate level
- Communicate commitment to personnel at all levels including:
  - Audit site and boundary
  - Audit objective(s)
  - Areas of audit
  - Verification of legislative and regulatory compliance
  - Assessment of internal policy and procedural conformance
  - Establishment of current practice status
  - Identification of improvement opportunities

The audits normally encompass the following areas, the contribution of the RECODRIVE approach is stated in the following table:
### Table 3 Recodrive contribution to environmental management

<table>
<thead>
<tr>
<th>Topic</th>
<th>RECODRIVE contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material management, savings and alternatives</td>
<td>RECODRIVE encourages the use of parts causing lower fuel consumption, but also may have extended life time.</td>
</tr>
<tr>
<td>Energy management and savings</td>
<td>This is the main RECODRIVE topic, contributing with fuel savings.</td>
</tr>
<tr>
<td>Water management and economy of use</td>
<td>n.a.</td>
</tr>
<tr>
<td>Waste generation, management and disposal</td>
<td>RECODRIVE also favours regeneration of used parts, if possible. Oil check is one variant of avoiding waste.</td>
</tr>
<tr>
<td>Noise reduction, evaluation and control (internal and external)</td>
<td>ECODRIVING has overlapping with a reduction of noise when driving, aiming at low RPM</td>
</tr>
<tr>
<td>Air emissions and indoor air quality</td>
<td>ECODRIVING reduces also main emissions harming the health</td>
</tr>
<tr>
<td>Environmental emergency prevention and preparedness</td>
<td>n.a.</td>
</tr>
<tr>
<td>Transportation and travelling practices</td>
<td>This is a main focus of the integrated RECODRIVE approach</td>
</tr>
<tr>
<td>Staff awareness, participation and training in environmental issues</td>
<td>This is a main focus of the integrated RECODRIVE approach</td>
</tr>
<tr>
<td>Environmental information publicity</td>
<td>This is a main focus of the integrated RECODRIVE approach</td>
</tr>
<tr>
<td>Public enquiry and complaints response</td>
<td>This is part of the integrated RECODRIVE approach (feedback). Especially with public transport avoiding abrupt braking will decrease complaints.</td>
</tr>
<tr>
<td>Environmental management system set up, suitability and performance</td>
<td>Supported by the RECODRIVE activities</td>
</tr>
</tbody>
</table>

*The RECODRIVE activities may be planned in view of an upcoming ISO14001 and EMAS accreditation.*
4.3. Procurement

Introduction

The procurement is influenced by internal and external factors. Both may influence total cost of ownership. Internal factors are specifications which seem to be fixed, but are not. For company cars specifying brands or number of cylinders is not a good idea, if you want to head for the most fuel efficient vehicle. Selecting fuel-efficient, low-emission vehicles does not have to compromise the ‘fit for purpose’ requirements of your fleet vehicles and can deliver up to 40 percent savings in costs and CO2 emissions.

During the procurement process of the vehicle (car, bus, etc.) there is significant influence of vehicle price, spare parts price, emissions, fuel type, fuel consumption and price, etc. Achieving an appropriate balance between those indexes, an optimum for fuel efficiency and emissions may be achieved at the same time.

External factors are the dynamic in demand, but also evolving technologies.

A new generation of fuel and engines creates new opportunities for saving fuel costs.

Environmental responsibility and good business sense may be especially shown in the line-up of your vehicles. The state or the regions are supporting the reduction of CO2-emissions funding procurement. Selecting the right vehicle equals making an informed decision – fuel economy often is only disclosed in tests in practice. The whole-of-life costs of a vehicle is derived by combining the purchase price, operating costs (parts and maintenance) and fuel cost with the vehicle’s residual value. A vehicle supplier usually can supply this information or - with a little bit of research - you can approximate this yourself. Vehicle management and monitoring possibilities should be included in the specifications.

It is of utmost importance that the procuring staff is knowledgeable about engine and vehicle technology or at least capable of integrating usability specifications with specifications from public tendering transport services and requirements for fuel efficient operation.

One very important factor is the size to fit. Vehicle size should be adapted to the needs of the application. Often the application has variable specification. With very high mileages per year unsuitable vehicle sizes create more costs than two vehicles to choose from. The following figure shows a distribution of kilometres and the time spent on the vehicle in the different applications – it makes clear that most of the time comfort for a velocity of 50 km/h and trips to 100km is sufficient.
Time on the Vehicle

![Graph showing distribution of trips, hours spent on the vehicle]

**Figure 4 Distribution of Trips, hours spent on the vehicle**

Comfort is heavily correlated with vehicle weight thus a decision on the vehicle comfort influences the consumption.

The decision-taking is founded on the capability to integrate the requirements from the users. A calculation of the total costs of ownership allows a good quality of the decision if the assumptions are o.k.
Figure 5 Qualification Procurement Process

Q.A. stands for quality assessment. Q.A. shall not add unnecessary checks or procedures but add only those having significant effect on the total cost of ownership and/or fuel consumption. This task requires a knowledgeable person who has outstanding experience with fleet management, the types of vehicles involved and the application. This person not necessarily has to be part of the management staff. Quality assessment might also be brought in via external advisors or at least by checklists.

Some questions are:

- Was it checked that the procurement decision is based on real world consumption held down in the specification and which might be evaluated in the operation?
- Is the procurement decision based on total costs of ownership including time for refuelling, maintenance and resale?
- What is the underlying cost model for the development of the fuel prices and wages in future?
- Is the alternative vehicle specification considering requirements or possibilities of the infrastructure (dimension, refuelling, charging, pressurizing, ventilation and safety issues...)
- Is the specification checked for refuelling and maintenance efficiency MTTF and sets thresholds for MTBF
- Are there aftermarket modifications possible in order to further reduce fuel consumption?
- Was there an assessment with regard to the whole fleet (e.g. may the solution be scaled up)

Generally the power of the buyer is limited when it comes to mass production, but it should be noted that without putting it on the agenda, the need for fuel saving is not recognised by the reseller but only their margin. When ordering a vehicle you have to ask for an engine and power train in general targeting your needs. Especially in urban or regional operation top speeds above 110 km/h are not necessary. Downsized engines, low speed tires etc. help also to save vehicle costs. Often a higher investment in procurement (mostly in terms of time) helps lowering the operation costs. For passenger cars the selection of the vehicle might be based on official labelling:

**How to check the fuel consumption of the make/model?**

**1st attempt - check the colour of the sticker**

The colour gives a first rough image whether the car is a fuel saver or fuel guzzler. If salesmen calculate fuel per seat, tell them the real need for seats you have.

Trying to follow the New European Driving Cycle with velocities up to 130 km/h and strong acceleration, smaller engines might consume 10% to 30% more than the official label says. A test published in the Austrian consumer journal “konsument 7/2008” showed an increase of 29% for the smart fortwo coupe 1.0 mhd. The good message for ecodriving pros is that with smaller engines and max. highway velocities of 110 km/h ecodriving helps to consume less than the label says.

The measured models with the lowest NEDC-compliant CO2-emission are Toyota Aygo 1.0, smart for two coupe 1.0 mhd and Opel Corsa 1.0 Twinport, all three staying below 140 g/km. Among those three most efficient car are two four seaters!

**2nd attempt check for % city and highway separately**

If you have high mileages and want to have a higher accuracy it is better to do your own calculations for each driving mode- inner urban, regional or long distance:

\[
M_{fuel} = \sum_{\text{for all modes}} \frac{km_{Mode} \cdot m_{fuel \_it \_that \_mode}}{m_{fuel \_it \_that \_mode}} \frac{kg}{km}
\]
Comparing different fuels the exact way of doing the comparison would be to account for the energy used. We may calculate in kg of fuel, if we want to compare similar fuel types at different temperatures, for the same fuel you might use volume (litres) of course.

**Alternative Fuels**

The utilization of alternative fuels is a possibility to lower the emissions and costs. Still simple utilization of the fuels is not sufficient to achieve a problem-free and more cost-efficient operation. Costs arising from insurance, fuel storage, safety requirements, emission-related taxes and fees etc. have to be taken into consideration as well as operational issues. Taxes and fuel costs might help to reduce costs. But before changing the fuel it is recommended checking the additional weight and load capability of the alternative fuel solution. The following figure shows the theoretical additional volumina, which might reduce the utilisable load volume when not embedding the tanks in the chassis.

![Figure 6 Weight and volume of alternative fuel tanks](image)

Concluding LNG liquefied natural gas and bio-oils/bio-diesel would be the most favourable alternative fuels with regards to volume requirements. Regarding electric storage, the optimisation will size the battery according to the operational logistics and determine the most efficient battery type. Additional weight is to be expected with electric but also highly compressed fuels and hybrid electric solutions increasing the fuel consumption.

Alternative power trains comprise battery electric and hybrid electric:

Battery electric saves most end energy and is suited for urban delivery, if charging logistics is manageable. Hybrid electric saves some end energy and is suited best for stop’n go and high share of fuel costs of the TOC – taxi sales soaring, buses might be
next. Plug-in hybrids or dual mode vehicles may allow zero emission for the last mile switching between hybrid and electric operation.

Alternative fuels may be biodiesel (FAME), ethanol or pure plant oil. CNG saves CO₂ by reducing the C, the energy demand may be higher when using spark ignition engines. But anyhow the CO₂ –savings survive if you have a second generation engine optimised to use the high octane methane. Additional to the C in the fuel you have to check motor efficiency too – a combination with hybrid power trains in stop'n go operation may be beneficial. E95 saves CO₂ by using biomass as feedstock, compression ignition engines allow similar efficiencies like diesel operation. Since ethanol supply is scarce in Europe apart from Sweden, buses are a good field of application. B30-100 saves CO₂ by using biomass as feedstock, compression ignition engines with very small adaptations may be used. Low blending is the simplest solution, warranty from the importer of external insurance is necessary for higher blending. PPO/SVO saves CO₂ by using biomass – fuel heating shall be retrofitted and start and stop made with fossil diesel. At constant (elevated) loads, less motor oil checks are necessary and the risk of damages of the engine is decreased.

**Gear Type**

The choice of the gear type has an enormous influence on the fuel consumption. With automatic gears it is important to differentiate between continuously variable transmission CVT, planetary gears with a couple of gears and automatically shifted sequential gears with many gears. While the earlier have more losses the latter do have the same losses as manual gears. In fact the only difference is that the clutch is actuated automatically and the gear choice is done by the computer.
The change of the final translation influences the consumption since the cruise point may be shifted. With passenger vehicle and vans there is less steady driving compared with long distance trucks:

Figure 8 Range of torque vs, RPM for different gear box types

The more gears a system has, the better it may approach the optimal efficiency. However, more gears often correlate with more weight which increases the power demand slightly. This added weight is beneficial if the additional gears are used for a longer period of time to reduce the consumption. Typical bad examples are airport buses with only three gears operated on the motorway. In most cases the vehicles were specified properly but during operation migrating to the wrong applications.
Weight as Fuel Guzzler

The last years have seen a steady increase of the passenger vehicle weight. The following figure shows the increase over time dropping also model names:

Figure 9 Weight increase of medium-sized passenger vehicles over the years

For heavy trucks the comfort gadgets are not so dominating, but for buses A/C and other features have raised the weight too.

---

1 Technology Review 09/2008
Figure 10 Historical Development of Prévost Cars’ Intercity Bus Weight

But unlike with passenger cars optimisation in terms of seats (low floor engines etc.) have been balancing the load to curb weight ratio.

It is also important to understand the causes of the vehicle weight excursion in the last years.

---

2 INTERCITY BUS WEIGHT REDUCTION PROGRAM PHASE 1 Prepared for: Transportation Development Centre Transport Canada by: Martec Limited Prévost Car and Virtual Prototyping Technologies Inc. January 2000
**Gewichtsspirale**

<table>
<thead>
<tr>
<th>GERMAN</th>
<th>ENGLISH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gewichtsspirale</td>
<td>Weight increase vicious circle</td>
</tr>
<tr>
<td>Komfort, Sicherheit, Leistung, Vielseitigkeit</td>
<td>Comfort, safety, power, versatility</td>
</tr>
<tr>
<td>Anpassung: Stabilität</td>
<td>Adaptation: stability</td>
</tr>
<tr>
<td>Anpassung: Motorleistung</td>
<td>Adaptation: engine power</td>
</tr>
<tr>
<td>Anpassung: Chassis</td>
<td>Adaptation: chassis</td>
</tr>
<tr>
<td>Anpassung: Package und Tankvolumen</td>
<td>Adaptation: package and tank size</td>
</tr>
</tbody>
</table>

**Figure 11 Weight increase vicious circle caused by introducing new customer demand**

Comfort, safety, power and versatility improvements (top blue bubble) needed increased engine power, this needs stiffer heavier chassis structures, leading to packing problems and increased tank size. Altogether the masses increased and the stability had to be re assessed introducing better chassis and driver assistance systems. So the most important part breaking this vicious circle is to reassess the vehicle specification in terms of maximum speed, comfort etc. Versatile solutions might be achieved by removable parts which does not increase weight in standard operation. One example are removable third rows in estate vehicles and vans. Other examples are detachable load compartments.
<table>
<thead>
<tr>
<th>GERMAN</th>
<th>ENGLISH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Woher die Kilos kommen</td>
<td>Where the kilos come from</td>
</tr>
<tr>
<td>Gewichtsentwicklung der BMW-3er-Reihe;</td>
<td>Weight increase BMW 3xx;</td>
</tr>
<tr>
<td>Oben: Maßnahmen zum Leichtbau</td>
<td>Top: measures light weight construction</td>
</tr>
<tr>
<td>Unten: zusätzliche Serienausstattung</td>
<td>bottom: additional standard weight</td>
</tr>
<tr>
<td>Sonstiges</td>
<td>Other</td>
</tr>
<tr>
<td>Antrieb</td>
<td>Power train</td>
</tr>
<tr>
<td>Fahrwerk</td>
<td>Chassis</td>
</tr>
<tr>
<td>Karosserieausstattung</td>
<td>Body equipment</td>
</tr>
<tr>
<td>Rohkarosserie</td>
<td>Body shell</td>
</tr>
<tr>
<td>5-Gang Getriebe</td>
<td>5-gear transmission</td>
</tr>
<tr>
<td>Außenspiegel rechts</td>
<td>Exterior mirror on the right</td>
</tr>
<tr>
<td>Elektr. verstellbare Außenspiegel</td>
<td>Electric operated exterior mirrors</td>
</tr>
<tr>
<td>4 Türen</td>
<td>4 doors</td>
</tr>
<tr>
<td>Servolenkung</td>
<td>servo steering</td>
</tr>
<tr>
<td>ABS</td>
<td>ABS</td>
</tr>
<tr>
<td>Katalysator</td>
<td>Catalystr</td>
</tr>
<tr>
<td>Airbags vorne</td>
<td>Front airbags</td>
</tr>
</tbody>
</table>

23/90  
G. Cebrat, FGM
<table>
<thead>
<tr>
<th>German Term</th>
<th>English Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitzbelüftung</td>
<td>Seat ventilation</td>
</tr>
<tr>
<td>Schlupfkontrolle</td>
<td>Traction control system</td>
</tr>
<tr>
<td>Kurvenbremsassistent</td>
<td>Curve-brake assistant</td>
</tr>
<tr>
<td>3. Bremsleuchte</td>
<td>3rd brake light</td>
</tr>
<tr>
<td>Kopf- und Seitenairbags</td>
<td>Head and site airbags</td>
</tr>
<tr>
<td>6-Gang Getriebe</td>
<td>6-gear transmission</td>
</tr>
<tr>
<td>3. Kopfstütze hinten</td>
<td>3rd neck-rest in the back</td>
</tr>
<tr>
<td>5 Sterne im Crashtest</td>
<td>5 stars in crash test</td>
</tr>
<tr>
<td>Elektr. Fensterheber</td>
<td>Electric window lift</td>
</tr>
</tbody>
</table>

**Figure 12 Weight increase BMW 3xx over the years and reasons for in- and decrease in weight**

This figure mentions several causes:

- Increase of gear number
- Powered helpers (either electrically or directly coupled to the power train)
- Safety devices
- Emission control
- A/C equipment

Of course it is not our intention to recommend deleting all safety devices, but some may not be necessary, if the vehicle is operated in urban areas only at lower velocities. With the number of gears it is similar: On motorways a longer translation is very helpful, whereas in city operation it means additional weight and losses without any benefit. In contrary in ECODRIVING it is also recommended to use less gears when shifting giving the sequence 1-3-5. Uphill however more gears are beneficial if the velocity should be kept.

An electric parking brake may be efficient with parcel services and necessary with disabled, but otherwise adds unessential weight.

The process of vehicle weight reduction leads to less comfort or a strategic engineering including more than one function in parts. But this is up to the manufacturer and procurements may only deliver specifications.
Maintainability of Vehicles and Parts

Good maintainability and efficiency indicators help to achieve a high overall efficiency. When procuring vehicles questions to the supplier are:

- How to check the motor and gear oil quality?
- Should there be two oil qualities in my operation profile?
- How to check pressure loss in air filters easily (without big men effort)?
- How to check spark plugs easily (for spark ignition engines)
- Is there an on board diagnosis for the engine with regard to fuel efficiency (comprising the fuel injection and combustion control)?

On-board Devices and Fuel Management

There are several possibilities of supporting fuel management by ICT Informations and Communication Technology:

- Fuel replenishing-based accounting (maybe using tanking cards, transponders, codes...)
- On-board fuel gauges (summarizing, logging...)
- On-board recording of driving style (exploiting the CAN bus with the help of ISO 11898)
- On-board driver feedback with regard to consumption, driving style

Fuel balances reduce also fraud. On-board fuel gauges are only necessary for older vehicles without CAN-bus and without direct or indirect quantification of fuel consumption.

On-board recording of driving style may record issues like idling time, traction control and ABS in operation, RPM excursions, RPM average, average velocity, acceleration time...

Finding the right solution requires that all departments involved in the value chain sit together and elaborate the most applicable solution for the fleets. For individual rewarding schemes having more than one driver special rewarding schemes focussing on the vehicle may help to overcome this.

How to go for the most fuel efficiency?

If you are procuring high volume standard vehicles your chances of getting what you need depend on the size of the tender. But even with smaller tenders you might team with a car finisher and check out some improvements. However, it depends on the national homologation, how far you might go by:
- Adding wheel covers, air baffles/spoilers improving aerodynamics
- Replacing for low resistance tires
- Going for special lubricants
- Modifying automatic gear selection
- Removing vehicle parts or having lighter replacements for them saving weight

**Passenger vehicles**

With passenger cars you have the MPG or l/100km figure to orient yourself; additionally you might check the following points for being sure that you may save more fuel in operation:

- Does your car have a gear shift indicator or a fuel gauge?
- Does your car allow using low viscosity oils?
- Does your car allow mounting low rolling resistance tires?
- Does your car have a regulated AC?

Motor power and vehicle weight are the main factors. Once you have been coping with the problem of self-esteem using smaller or low-powered cars you have solved the problem. Especially in company fleets this is the crucial point.

When comparing vehicles check for the consumption in the respective driving cycle which applies to your main operational regime. A vehicle with a better overall fuel efficiency might be worse in your special case – for example in city service.

Insist that hybrids and special ECO-variants are offered to you by the sales personnel.

![Image of an aerodynamic front of an ECO-vehicle mock-up](image)

**Figure 13 Example of an aerodynamic front of an ECO-vehicle mock-up, which is now out of production**

While for fast highway driving aerodynamics is most important. In stop'n go traffic hybrid electric vehicles are saving most fuel.
Figure 14 Example of an power split hybrid electric power train

Power split allows electric driving only and charges the batteries when driving with the internal combustion engine ICE.

Trucks

The respective questions for truck procurement are;

- Does your tractor have an adaptable deflector?
- Does your semi-trailer have a tire pressure monitoring system?
- Are your tarpaulins tight and the semi-trailer inflated from the front side?
- Are all non-steering covered?
- Does it have direct heating/cooling without the need for idling?
- May you use super single tires?
- Does the tractor have an open interface to fleet management systems?
Super single tires might reduce a couple of problematic items like energy consuming tire kissing, uptake of stones etc. Pressure monitoring should be mandatory if it takes to much time to check all wheels on a regular basis manually or your tires are not new. Especially if you drive off-road partly or on roads not cleaned after accidents the risk of pressure loss is high.

Otherwise you should check for the above mentioned issues and off course the tire pressure especially after the ambient temperature has changed sharply.

If you are running the tractor over a longer period of time with a certain power, e.g. having similar loads at the routes, a more in-depth analysis of the efficiency map of the engine and the final translation of the axle is useful in order to optimize the fuel efficiency.

Since the fuel consumption is also depending on the semi-trailer (tarpaulin, front air intake, vortex generators etc.), it makes sense to differentiate the price when offering hauling of semi trailers to third parties.
Buses

With bus procurement the following questions apply:

- Is there a low-weight option using high yield strength steels or aluminium components for the self-supporting bus body?³
- May the buses be cooled/heated or pressurized from the external before the start of the engine saving idling time?
- If no, how long does the idling take to be able to move?
- Does the A/C or heating stop when the doors and/or windows are open (for a longer period of time)?

Some questions are identical to other vehicles like:

- Does the bus have an open interface to fleet management systems to be able to record ecodriving parameters?
- May you use super single tires?
- May you switch to low viscosity oils reducing friction?
- Is it possible to check the pressure loss in the air filter?

Figure 17 Bus body, bus wheel cover

Buses are tested frequently by the user before placing larger orders. This way you can see what the actual consumption will be. Be sure that you test them in regular operation with realistic passenger load.

If you intend to use buses on other terrain or routes (airport shuttle instead of inner city line) - more gears or at least a wider translation range, are helpful. The final translation should allow the motor to run on low RPM even at higher velocities. At higher velocities the cross-sectional area and the aerodynamic drag factor are becoming more important increasing the drag.

³ For new materials, new problems might arise with contact and salt corrosion but may be solved.
Regarding bus size, the trade off between bus operation cost and labour cost when using trailers has been partly reduced by introducing automated coupling. Having parking space for abandoned trailers tour and load coincidence (one tour with high load with and others with low load and without trailer) is mandatory.

4.4. Driver

When talking about employees the managerial skills have to include psychology - drivers are facing several inconveniences during their work:

- Road rage
- Attention to sometimes hidden traffic regulations facing personal consequences when offending
- Pressure from fixed or latest delivery time or sequences

Navigating has become easier for the driver with the help of electronic aids, but the inclusion of truck related info is only on its way and not common so far.

For bus drivers additional stress is created by:

- Complaining or misbehaving passengers
- Lacking pre-emption at traffic lights
- Ticket sale

The ECODRIVING concept should address those issues in order to achieve a trade-off invest in social care and profit from better service quality and fuel savings. On the other hand the operator should support enforcement of bus priority when leaving stops (add stickers to the back of the bus) and at intersections (talk to traffic planners).

Qualified drivers are a scarce resource nowadays, required driver training is extended and expensive. Therefore all actions should have into mind that frustrating drivers by punishing schemes is costly creating additional fluctuation. On the other hand monitoring fuel consumption might prevent from fraud and help much more than initially expected. So potential damage and additional burden have to be balanced.

Directive 2003/59/EG has been setting up new rules for the member states how to achieve better status in driver skills for heavy vehicles (driver license type C,D,E...). The newly introduced requirement for additional training of vocational drivers in national legislation offers the chance of implementing ecodriving on a very broad basis. The mandatory lessons might be used to go deeper into ECODRIVING. The regulation which may differ for the member states typically require vocational training of 35 hours each five years starting with 2008/2009. The training has to be made by certified institutes.
(maybe also internal to the fleet operator if certified). The first trainings have to take place at the latest 5 years after obtaining the driver licence. The vocational bus drivers have time till September 2013, truck drivers one year more (maybe different in your country).

Training for drivers is the key element in ECODRIVING. We know general broadcasting of ECODRIVING info over mass media; computer-based training, training in confined area and in real traffic. Hands-on training in real traffic is preferred and has a return on investment of less than a year, sinking. The reason for opting to hands-on training is that only theoretical info will not convince drivers who have been driving already for a long period of time. Only the effect showing reference and improved fuel gauge reading will persuade them. The theoretical training shall cope with wrong beliefs and support that the changes are beneficial in every sense, e.g. that there are no trade offs in terms of travelling time or engine service life when applying ecodriving.

The training consists of two to three trips:

- In the first the reference value is measured having no trainer on board or watching and no theoretical training before (approximately). Then theory behind Ecodriving is explained.
- In the second trip the trainer advises the driver (optional).
- In the third trip finally the result from the training is measured.

![Figure 18 Process hands-on driver training](http://onlinepubs.trb.org/Onlinepubs/circulars/ec013/4BNelson.pdf)

There are training companies who offer advice during the trip only as add-on. This advice is seen as embarrassing for the drivers and reduces reflection. Anyhow, it is admitted that for some drivers the advice during driving is needed to advance understanding.

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If you order driver training, check out the quality of the approach: A good approach creates understanding for the driving. Second best is to give the entire staff concrete advice which might be only applicable for certain vehicle types or technologies. There should be separate training units for Diesel and Otto engines at least.

Since we go beyond Eco Driving in RECODRIVE, additional experiments during the training may include trips with different engine size, additional weight on board, A/C on and windows open etc. This might be done more cost efficiently using CBT computer-based training, but is also feasible using real cars.

Eco Driving and psychological care are leading to so-called green driver types, creating additional benefits as reduced frequency of accidents and less time spent on refuelling:

<table>
<thead>
<tr>
<th>Variables</th>
<th>Class 1: Red Drivers</th>
<th>Class 2: Green Drivers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Samples</td>
<td>663</td>
<td>531</td>
</tr>
<tr>
<td>Driving Hours Between Petrol Station Visits</td>
<td>7.4</td>
<td>8.8</td>
</tr>
<tr>
<td>Risk Index</td>
<td>56.3</td>
<td>14.1</td>
</tr>
<tr>
<td>Kilometers per Liter</td>
<td>29.1</td>
<td>31.3</td>
</tr>
<tr>
<td>Days Between Petrol Station Visits</td>
<td>3.0</td>
<td>5.1</td>
</tr>
</tbody>
</table>

Table 3: Higher Risk Driving Negatively Impacts Petrol Consumption

Figure 19 Risk index depending on driving style

When changing the driver attitude, the time spent for refuelling is lower as well as the risk concerning fatalities.

---

4.5. **Maintenance**

When checking maintenance quality you should have an eye on:

- Excess weight, which is carried around without any purpose
- Roof deflectors, which are not adapted to the container or load height
- Under inflated tires
- Kissing twin tires
- Small load factors
- Leaking pneumatic systems (easily detectable during operation having the compressor often running or sound from the blow off or leak)

Some hidden problems require in-depth analysis like:

- Axle misalignment
- Tire toe-out
- Dragging brakes
- Low oil grade
- Clogged air filters
- Smaller leaks in the pneumatic system
- Engine Management (injection timing, ignition timing for spark ignition engines etc.)

4.6. **Monitoring**

There are two different monitoring strategies. You might make use of a fuel management system or use on-board units for monitoring the driving style and optimising logistics. On the other hand you can order the vehicle with lower power or with a speed limiter.

Having more drivers during one measuring period does not necessarily require highly sophisticated systems – savings of that vehicle may be attributed to the drivers in relation to their driving time as first approach. Social interaction will do the rest if they are able to communicate.

**Table 4 Fuel efficiency monitoring variants**

<table>
<thead>
<tr>
<th></th>
<th>Vehicle-bound Monitoring</th>
<th>Driver-bound Monitoring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indicators (idling time, RPM…)</td>
<td>For special applications with team evaluation</td>
<td>For special applications with individual evaluation</td>
</tr>
<tr>
<td>Fuel consumption</td>
<td>Least complicated</td>
<td>Standard method</td>
</tr>
</tbody>
</table>
The main saving lies in detecting forced stops early and approaching with the highest gear, but no gas. This is not detectable directly via monitoring, maybe the time using higher gears without gas may be recorded, but this also would comprise slight downhill coasting, so the indicator is only useful in plains.

Monitoring systems increase the value of older vehicles and increase the potential savings with them. Check compatibility with newer vehicles, so you may take them with you when procuring new. Oldest vehicles without CAN bus system may require different solutions and may be left without such systems saving costs significantly for the overall system.

### 4.7. Rewarding & Recognition

The recognition or rewarding scheme may be team-based having the same reward for the group or even have a reward that they may consume together only or focus on individuals having separate rewards for each of them. You may also combine. Here are two extremes:

- Plaques and trophies handed out to drivers or teams at annual awards at a company banquet
- Individual bonus scheme (non disclosed)

Since the rewarding may create discussion in the teams or not have the desired impact we give some hints here:

Yearly or monthly awards leave the not winning rest frustrated. Not disclosed financial bonuses do not motivate staff needing intrinsic motivation. Discuss with your staff what they would see as a reward.

A big issue is the dynamic of the scheme. Procurement may lower the base value of the fuel consumption. Maintenance staff and drivers may have an influence of the same size. A fair scheme should reward all of them equally and to define the right base value for the drivers. It is very important to note that rewards should not be seen as part of the ordinary salary.
Incentive programmes should reward the outcome variable, not variables within the process, if possible like one driving parameter recorded. If fuel consumption may not be used, a point system allows giving different indicators different weight and construct a single output indicator.

After the scheme was set up, a checklist shall be applied ensuring that the scheme is perceived as fair and equitable by all the staff:

- Are the rewarding scheme and the weighing clearly understandable and fair to everybody?
- May all the staff achieve rewarding with the same effort or may there be free riding or a limitation of the rewarding to a few?
- Are the savings attributed to the right staff?
- Is the rewarding near the action and frequent enough to keep the performance?
- May feedback from customers with regard to lower service quality interfere?
- Does the scheme include rewarding variants for all types of personalities in the company?
- Is the scheme supportive for the team spirit?
- Is there a possibility for the least successful to catch up having trainings or discussion with procuring and maintenance staff?
- Is the reward sticky or slippery?
- Is wage taxation watering the reward heavily?
- Is the rewarding damaging continuous improvement?

Communications with staff is important, a positive wording mandatory. Drivers who are not eligible for a reward should understand why. Those who are eligible should be seen by others as someone who deserved it.
5. Background Driving Forces – Where does the fuel consumption come from?

This handout gives the theoretical background, so you may solve problems were no ecodriving measures are described here on your own or understand the hints better.

5.1. Forces, Power, Energy

The necessary forces to move a vehicle result from four main drivers:

Aerodynamic drag

\[ F_{\text{drag}} = A_{\text{cross}} \cdot C_d \cdot \frac{v_{\text{air}}^2 \rho_{\text{air}}}{2} \]

where \( F \) stands for the force, \( A_{\text{cross}} \) for the cross-sectional area of the vehicle, \( \rho_{\text{air}} \) for the density of the air and \( v_{\text{air}} \) for the relative velocity of the air (incl. wind). Typically bad \( C_d \) may be deducted from the side view easily (see figure).

Figure 21 Vehicle with high aerodynamic drag

The cross-sectional area is sometimes higher than needed, especially for SUVs, vans or tank trucks having a semi trailer with smaller cross-sectional area:

Figure 22 \( A_{\text{cross}} \) wasted by unsuitable tractor
All gaps are increasing the drag factor.

Figure 23 Airflow with semi trailers and tractors - creating a higher drag factor without deflector

---

7
**Internal friction**

Internal friction occurs in the engine and the power train each time two solids directly in contact or separated by a liquid (lubricant) move with relative speed to each other. The internal friction depends on the type of materials for dry friction and the lubrication.

**Rolling resistance**

\[ F_{\text{roll}} = \mu_{\text{roll}} \cdot m_{\text{vehicle}} \cdot g \]

where \( \mu_{\text{roll}} \) stands for the rolling resistance coefficient, \( g \) for acceleration due to gravity and \( m_{\text{vehicle}} \) for the vehicle mass. The rolling resistance is dominating at lower velocities over the aerodynamic drag.

**Acceleration**

\[ P_{\text{accel}} = m_{\text{vehicle}} \cdot a \cdot v \]

where \( P \) stands for power, \( m_{\text{vehicle}} \) for the total vehicle mass, \( a \) for the vehicles acceleration and \( v \) for the vehicles velocity. The acceleration energy is dominating in stop’n start operation.

Hybrid electric and battery electric vehicle might regenerate deceleration energy, but not totally because of internal losses (friction, electrical losses...) of the regeneration system. Nowadays apart from electric also hydraulic and pneumatic systems try to enter the market. They may create less investments but do not offer the same flexibility as electric power trains.

At constant 130 km/h, the biggest loss is caused by the aerodynamic drag. The drag increases with the third power of the velocity- the force has to be multiplied by the velocity to get the power loss.
Figure 24 Resistance for cars at 130 km/h

While with 130 km/h you have a consumption of 6.5 l/100km, with 160 km/h you would have 1.86 times the consumption, equalling 12 l/100km. This saves approx. 6€ per hour and adds 20% more time at maximum. Thus sticking to the speed limits pays off for hourly fees below 30€/hr if you don’t account for fines and additional wear and tear.

With trucks the cab/trailer design (aerodynamics) has the same importance as the tire/wheel system (drag and tire) for the fuel consumption, because of the lower velocity.
The aerodynamics causes 35-40% of the losses, tires 42-45%. Larger variances are shown with regards to the transmission (drive train) ranging from 7-16%, the lower value for long distance motor way application. The auxiliary devices like A/C including fans are consuming 7-8%.

**Figure 26 Resistance for trucks on motorways**

**Fuel consumption by driving modes**

In urban cycles, the biggest energy consumption is with cruising closely followed by starting (acceleration from still stand). The following chart shows that most may be saved when coming to still stand (avoiding it if possibly by coasting) and in the starting phase (reducing RPM and accelerating stronger) – this is not the case for full blown hybrid electric vehicles which may regenerate braking energy.
Energy demand may be kept low by:

- Lower parasitic masses (compared to the average load) causing low energy demand in transitional operation (stop and go operation in the cities) Five seaters of the sixties had 625 kg. Japanese sub-compact cars have 500-600 kg. Further mass reduction is possible by adapting the maximum number of passengers to the average occupancy rate and having removable seats. Two-seater microcars have less than 400 kg, single-seaters less than 300 kg. Further reductions are possible with very light construction, e.g. twike. Thus extreme vehicle masses might go down to 300 kg for ultra light vehicles from today’s 1100 kg to 1600 kg. The crash protection is certainly a problem in the SUV-poisoned environment, but the low energy vehicles are driven mainly at low velocities in cities. Anyhow energy absorption shall be increased for heavier cars by design and integrating aluminium foam or other energy consuming elements.

- Looking at the vehicle statistics doubling the vehicle weight from 1000 kg to 2000 kg adds 125% fuel consumption on average giving 9 l/100 km instead of 4l/100km for a diesel engine. This increase is not only caused by increased drag, but also by
a smaller efficiency of the bigger engine at part load and the ancillary devices present with bigger and more expensive cars.

**Fuel Consumption: Diesel vs. Gasoline**

![Fuel Consumption Graph](image)

**Figure 28 Weight influence on fuel economy**

- Low cross-sectional area and mirrors replaced by cameras causing very low drag losses, especially when driven at higher speed. Two seating places in a tandem (back to back or forward facing in line like for Volkswagens 1l car) arrangement drastically reduce the cross-sectional area down to 1 m². The drag coefficient $C_d$ of the vehicle may be as low as 0.15 for very good vehicles.

The fuel consumption is thus influenced by:

- Engine type, size and their efficiency in practice
- Transmission now introducing modern gearbox concepts with automatic shifting instead of automatic gears
- Vehicle weight
- Air drag resistance
- Low resistance tires (and low cross-sectional area of tires)
- Choice of the best suited oil
- 2WD or 4WD

For the potential savings the differences for the various applications (stop’n go, long distance) are visible.

Summarising we have the following fuel saving groups:

- Fuel consumption by driving modes
- Factors affecting energy consumption (factors pre-drive and during driving)

The next power train concepts on the market will be progressing from lean to strong hybrid electric power trains and later possibly switching to battery electric vehicles with power generator which then in the end may be fuel cells with only a small hydrogen or Bio-Ethanol storage tank.

5.2. Losses aerodynamic drag

The drag resistance is influenced by the cross sectional area which means that smaller cars with small tires have lower losses. Racks and bull bars are detrimental.

![Figure 29 Aerodynamic drag](image)

As an exception from the rule containers for long pipes mounted at the roof of passenger cares certainly are more fuel efficient than using a bigger van where the tubing may be carried in the vehicle.
Figure 30 Roof mounted containment

The second influence is the drag factor. It has been decreasing in the last years, but the lower end of the fleet in operation stays at 0.28 since the eighties.

<table>
<thead>
<tr>
<th>Air drag coefficient of VW and AUDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drag coefficient $c_D$</td>
</tr>
<tr>
<td>0.50</td>
</tr>
</tbody>
</table>

More extreme concepts have not been successful like the first Honda Insight or not even appeared in the dealers show rooms yet.

Figure 31 Drag factor improvement, droplet form

Due to the length limitations for the vehicle we have to compromise - a perfect drop size form (boat tail) would be best but adds much length. Practical solutions reduce the drag at the rear end by adding vortex generators.
Figure 32 Drag factor improvement, details

Smaller outside mirrors might be against the law. Maybe there is a chance to replace them by a camera. Have also a look at your vehicle from the ground; all the surface where air flow passes above creates drag and might be covered by plates.

There are already special eco-versions of passenger cars available including most of those improvements.

Figure 33 Fixed wheel cover F1

Ferrari was the first to use front wheel covers in Formula 1, which do not rotate as they are attached directly to the central wheel fixture. In practice those wheel covers might not look that dangerous.

For trucks the wheel covers, air deflectors and pressurized tarpaulin covered containments are helpful reducing air drag.
Figure 34 Aerodynamic truck

For semi-trailers the solution is not so easy; manufacturers experiment with inflatable parts between tractor and semi-trailer - also at the rear end.

Figure 35 Aerodynamic measures tractor and semi-trailer

8 sources IVECO and http://www.goodyear.com/truck/pdf/radialretserv/Retread_S9_V.pdf
Other improvements like vortex strake trailer base treatment devices are less introduced on the market.⁹

Even for special requirements like flashing lights or trailers, solutions improving aerodynamics do exist (but those ones seem to be sub-optimal):

![Drag factor improvement, special applications](image)

**Figure 36 Drag factor improvement, special applications**

### 5.3. Losses power train

Looking at an internal combustion engine, we see that only 30% of the inputted energy may be used in practice at high power and 11-12% of it at low average power. With an idling engine, the sole power demand is internal friction.

---

⁹ Simple and Low-Cost Aerodynamic Drag Reduction Devices for Tractor-Trailer Trucks Richard M. Wood and Steven X. S. Bauer SOLUS – Solutions and Technologies
**Figure 37 Losses in ignition combustion engines**

The biggest influence for the fuel economy is certainly the engine power acting over the number of cylinders, displacement etc. increasing internal friction. Having an engine power of 60kW the friction in the engine is 12kW. Engine efficiency is affected by:

- Type of engine (compression ignition or spark ignition)
- Use of exhaust power (turbo charger)
- Valve control, also controlling amount of compressed air (Miller/Atkinson cycle)
- Engine software creating power excess
- Start/stop functionality or braking power regeneration

Good fuel economy is achieved by reducing internal friction. This concerns the engine applying the following measures:

- Offset crankshaft (avoiding sort of jamming of the piston ring)
- Coating with molybdenum disulfide of roller rocker arm and piston skirt
- CrN coated oil ring and bearings in general
- Replacement of slide bearing by ball bearing

But friction concerns also the gear box, the differential etc. Having 60kW engine power the friction in the gear consumes 3kW, while the axle transmission/differential consumes 2kW.

![Friction losses in the overall drive train](image)

**Figure 38 Friction power train**

It is important to know that the friction is depending more on RPM than on torque, therefore we have higher internal specific losses in city operation. **Thus special motor oils adapting to the ambient temperature and the operational mode may save more in city operation.**
It is often said, that more powerful vehicles run more efficient on higher speed. This is very dangerous, since the argument may lead to buying a stronger than needed vehicle. As we have seen power depends on the third power of the velocity. We have also a slight decrease in engine efficiency beyond the max. torque. So on overall you might save fuel with a stronger engine when going fast all the time, but generally you certainly lose...
money, because bigger engines have higher mass and more friction which leads to additional losses in non-continuous and low-velocity operation. Varying a little with the vehicle, the maximum fuel economy is at 55mph or 83 km/h but you are on a very flat plateau so you might drive slower without deteriorating it much. But speeding certainly consumes more fuel.

![Figure 40 Optimal cruising velocity](image)

Speeding also reduces life time of tires as the following figure shows:

![Figure 41 Tire life time depending on velocity](image)
Off course speeding adds also to increased cost for clutches, brake pads etc...

**5.4. Losses wheels and tires**

With regard to **tire procurement** it may be shown that there should be an adaptation of the requirement profile (mainly top velocity) depending on the application. It might also be shown that tire size and tire weight have influence on the drag.

Low **rolling resistance** might be achieved by smaller and high-pressure tires with optimised tread and low vehicle mass driving the rolling resistance. Advanced driver assistance warning if the distance is not sufficient and ABS could prevent safety problems caused by the small tires. Values of $\mu_{\text{roll}}$ down to 0.0025\(^{[8]}\) are possible, but are more usually 0.005 to 0.008 for bicycle-type tires and 0.010 to 0.015 for car tires. With twin tires the drag is also influenced if the diameters do differ or stones are embedded.

A test of summer tires by the Austrian consumer information bureau VKI revealed that the difference between the worst and the best tire is a consumption of 0.3 to 0.5 l/100km. Other parameters to be taken into consideration are durability, grip, comfort, aquaplaning and noise. Low resistance tires have to compromise behaviour under wet conditions, but benefit durability.

<table>
<thead>
<tr>
<th>GERMAN</th>
<th>ENGLISH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jeder Reifen stellt ein abgestimmtes System zur Erzielung von Allround-Eigenschaften dar</td>
<td>Each tire represents an aligned system for the achievement of allround-characteristics</td>
</tr>
<tr>
<td>Geräusch</td>
<td>Noise</td>
</tr>
<tr>
<td>Rollwiderstand</td>
<td>Rolling drag</td>
</tr>
<tr>
<td>Laufleistung</td>
<td>Mileage</td>
</tr>
<tr>
<td>Aquaplaning</td>
<td>Aquaplaning</td>
</tr>
<tr>
<td>Nassgriff</td>
<td>Wet grip</td>
</tr>
<tr>
<td>Fahrkomfort</td>
<td>Driving comfort</td>
</tr>
<tr>
<td>Bewertung &gt;100% ist “besser”</td>
<td>Assessment &gt;100% is “better”</td>
</tr>
<tr>
<td>Referenz</td>
<td>Reference</td>
</tr>
<tr>
<td>Systemeingriff zur Veränderung von Eigenschaften</td>
<td>System intervention for change of the characteristics</td>
</tr>
<tr>
<td>Jeder Eingriff in dieses System – mit dem Ziel selektiver Verbesserung bestimmter Eigenschaften – führt zu einer Veränderung des</td>
<td>Each intervention in this system – with the objective of selective improvement of certain attributes – leads to a modification of the whole</td>
</tr>
</tbody>
</table>
Figure 42 Fuel efficient tire design factors

Whilst the antagonism between safety and fuel efficiency is true for today’s technology, new inventions might come up with a break through. Apart from new materials for example, it might be useful to combine two types of wheel in one (having more grip on demand) and control the grip with the tire pressure levelling out load issues.

Please note that - especially for scooter tires - the shape is also important and not only the outer material. Slim, but fully regenerating sidewalls are transforming less energy into heat.
5.5. **Ancillary Consumers**

In the last years we have seen a couple of consumers entering the car:

- Power amp
- On board computers and build in navigation devices
- Air conditioning
- Charger for nomadic devices
- Window opener
- Door opener (also for trunk and liftgate)
- Seat adjustment
- Distance keeper
- Seat heating and ventilation
- Mirror heating and folding back
- Windshield heating avoiding condensing in the interior (fog prevention)
- Rain sensing windshield whipers
- Parallel parking system

At least the introduction of LED technology has helped to reduce the power needed. Air condition certainly is the biggest consumer in the list but all devices add to the vehicle weight adding to the fuel consumption.

5.6. **Comments about Electric and Dual Mode Vehicles**

Electric vehicle do have quite some problems in terms of design optimisation. Increasing autonomy entails higher weight and thus a rising energy demand. Combined with inefficient production of electric power to the grid there is no efficiency gain. With dual mode vehicle this problem is solved by introducing an engine which might be used for long distance travel leaving the electric system smaller. This engine might be phlegmatized having lower consumption. Larger energy storage is not required. Charging the energy storage with the Internal Combustion Engine ICE leads to a serial hybrid electric design, which is a good idea for low max. power requirements. Otherwise the added mass by generator and electric motor in a serial hybrid design would be too high. Plug-in hybrids are HEVs which were not meant to operate in electrical mode for longer distances; Retrofitted with larger batteries they might have thermal problems in the electrical system, but not necessarily.
Table 5 Recommendation for the use of Hybrid power trains, source SUGRE project

<table>
<thead>
<tr>
<th>Application</th>
<th>Service with forced stops?</th>
<th>Stop’n Go Traffic?</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban route bound buses</td>
<td>Existing and passenger stops defined precisely</td>
<td>Frequent</td>
<td>Large savings</td>
</tr>
<tr>
<td>Utility vehicles for street services (snow plough, cleaning...)</td>
<td>No</td>
<td>Partly when oscillating operation (driving back and forth)</td>
<td>No improvements with constantly moving vehicles</td>
</tr>
<tr>
<td>Collecting domestic waste and recycling materials</td>
<td>Yes frequent but not defined precisely</td>
<td>Very frequent</td>
<td>Large savings if auxiliary devices are electric</td>
</tr>
<tr>
<td>Servicing public bins and other street furniture</td>
<td>Yes frequent and defined precisely</td>
<td>Less frequent</td>
<td>Significant savings</td>
</tr>
<tr>
<td>Courier, express and parcel services</td>
<td>Infrequent (only at traffic lights)</td>
<td>Mostly on intersection with traffic lights</td>
<td>Significant savings in cities</td>
</tr>
<tr>
<td>Distribution retail (postal, milk...)</td>
<td>Depends on number of clients per trip</td>
<td>Only on intersection with traffic lights</td>
<td>Significant saving in cities</td>
</tr>
<tr>
<td>General service traffic (maintenance staff)</td>
<td>Infrequent (only at traffic lights)</td>
<td>Only on intersection with traffic lights</td>
<td>Slightly improved</td>
</tr>
<tr>
<td>Medium and Long distance freight</td>
<td>Very few</td>
<td>Only in cities and at congested highways</td>
<td>No increased efficiency</td>
</tr>
<tr>
<td>Heavy truck in pits and plants</td>
<td>often</td>
<td>Rather no</td>
<td>Significant savings for small stretches served</td>
</tr>
</tbody>
</table>
6. Where to save most - Fuel consumption and vehicle choice

This handout points to the influence the procurement has on the fuel expenses during operation.

### 6.1. Vehicle Type

The biggest influence is selecting the right vehicle. Assuming that a two seater consumes 4l/100km and a four seater 6l/100km and you have 90% two person operation and 10% four person operation having two drivers and two vehicles the total fuel consumption accounts to:

\[
90\% \cdot 4l/100km + 10\% \cdot (4 + 4)l/100km = 4.4l/100km
\]

Operating only one car for each case we even get a lower overall fuel consumption:

\[
90\% \cdot 4l/100km + 10\% \cdot 6l/100km = 4.2l/100km
\]

Compared to the utilisation of only one bigger car with a consumption of 6l/100km you save 27%-30%. If you avoid owning two cars you may save more money, because you also save finance and maintenance costs. So car sharing might be a good alternative.

Of course the eventual need to pickup persons etc. might invalidate this calculation, but it shows that investments steers your total cost of operation. Often having two solutions one for 30% of the demand and one for 60% is best suited to have lowest overall costs. Additional cargo capability (external) or emergency seats (2+2) are also available with very small cars.

For example a small vehicle operating only at peak load will return to the depot - instead of doing so it will step in for a larger vehicle which is not needed in off-peak time. While the driver is off duty after driving the big vehicle to the depot the small vehicle exchanges the big one and leads to lower total cost of operation. Even a small detour to organise the hand over is possible and necessary not to create problems with shifting load from one vehicle to the other. With public transport the problem is not that severe.

For freight and passenger transport logistics is the key – cross exchange of vehicles while driving etc. might give a better overall performance since the first thought is always to have the biggest vehicle that may handle all jobs. But this first thought creates higher total cost of ownership if the vehicle is not used according to its maximal load.
Busses and Trucks

Fleet managers with buses and trucks have less influence on the engine power and vehicle size since it is dictated by the load and not the sentiment of the buyer. Focusing on logistics we may introduce new concepts:

- Trailer concepts
- Having the right fleet composition

If you look at efficient public transport you might want to check the following solutions:

![Bus trailers](image)

**Figure 43 Bus trailers**

In some countries however it is not allowed parking trailers in cities! Trailers are only useful if the timetable allows parking them for one run. E.g. very long tours with high fluctuation of passengers from tour to tour do not profit from trailer concepts.

### 6.2. Vehicle Quality

The quality of a vehicle is reflected not only in the price, but also in the fuel consumption. The biggest savings lay in the number of cylinders/engine size and the comfort introduced by additional mass. For passenger cars the fuel consumption is measured in a standardised test. Since it is not included in this test check also fuel consumption of:

- Air condition
- On-board entertainment
- Other electric consumers with a higher on-time

If those consumers are on for a longer period of time the average fuel consumption is higher than that of the test (label).
Fuel economy indicators

Indicators for fuel efficiency are assisting the driver to obtain low fuel consumption.

- Indicators for fuel economy of vehicles have been developed by car manufacturer for helping to ordinary people drive with their eco-driving mode, substantially.
- Various type of eco-driving indicators can be expected to implement to all passengers’ cars as well as to public sector’s cars.
- It is possible to know the transition of fuel economy and the improvement of driving technique toward eco-driving by utilizing such as eco-driving support systems.

![Eco-driving Indicators in Passenger’s Cars](image)

**Figure 44 Fuel economy indicators**

The devices do have simple indicators, a bar or complex data about the trip. Practice has shown that in city operation people do not believe in indicators showing the current fuel consumption. This figure might not be very helpful also for adapting the way of driving since it shows only the figure of the last second. A long term average on the other hand might not show clearly if a driver improves during the trip. So an intermediate solution is required. Showing only the efficiency in the engine map does not reveal additional consumers nor gives an indication of the influence of the velocity.

For tractors the overall efficiency depends on the semi-trailer. Thus the main quality criteria is the aerodynamics of the semi-trailer:

**Side skirts**

Side skirts are plates which are mounted on the sides of trailers, primarily with a view to underrun protection. The new aerodynamic design of the side skirts substantially reduces the air currents alongside and under the trailer and thus also the air resistance. Initial driving tests with a trailer equipped with the aerodynamic side skirts over a straight
stretch of public road revealed a cut in fuel consumption of between 5% and 15%. Subsequent research comprising long-term operational tests by TNT displayed a fuel reduction of 10%. These results confirm the calculations and findings from the wind tunnel tests: These had already established that the observed 14 - 18% reduction in air resistance led to 7 - 9% less fuel consumption. In practice, the figures are even better.

See also Figure 35 Aerodynamic measures tractor and semi-trailer

**Boat tail**

Road tests have also already been initiated on what is known as boat tails. These constructions on the rear of a trailer ensure a reduction in the wake: The vacuum and air currents arising when the trailer is moving. In theory, a boat tail could also mean a cut in air resistance of 30%, with a fuel reduction of 10 -15%. For practicality reasons boat tails are minimized:

*Figure 45 Aerodynamic trailer tail*

Limitations in their practical use, in particular when loading and unloading, safety aspects and problems with exceeding maximum vehicle sizes prevent them being used in many types of vehicles. Research focuses on gaining knowledge and developing different practicable solutions.
Tire pressure control

There are systems inflating the tires when running or systems alerting the driver in case of a pressure loss. Quality of the systems is expressing itself in the robustness when changing tires or against bad weather and salt. Using such systems is recommended when deflating risk is high and twin tires are used, because different diameters caused by differing tyre pressure are increasing the drag.

![Figure 46 Aerodynamic trailer tail](image)

The left figure shows stones which are increasing drag and risk of punctures, the right figure shows twin tires having different diameter (without load). This may not only be caused by different wear, but also by different tyre pressure.

**Weight/Load capacity**

Check the semi-trailer quality by assessing the load per weight ratio. Step-down trailers might be a good compromise offering more load volume at a only slightly increased trailer weight.

6.3. **Vehicle Use**

**Consolidating load** may save 20-35%. This comprises round trip pick-up or delivery (milk run) and/or cooperation (freight exchange).

Real time operational control of the fleet is said to have 10% savings. Using two-way communication with the driver together with positioning allows implementing automatic rerouting. This might only be a small improvement over the solution using mobile phones, but creates other savings which would have resulted from defaulting drivers, who are not part of a tracking scheme.
Ecodriving alone may save 5-7% depending on the rewarding system, including driving style only as measure.

### 6.4. Supportive Devices – Add-ons

The biggest saving lays in the (ab)use of air condition for passenger cars. For trucks additional heaters may reduce idling losses significantly. For buses and trucks idling is also caused by slow filling of the pressurized air system. The potential savings are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Passenger Cars</th>
<th>Truck Buses</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Driver</strong></td>
<td>-7% Ecodriving (max. 20%)</td>
<td>-8% Ecodriving (on average)</td>
</tr>
<tr>
<td></td>
<td>-5% Idling reduction</td>
<td>-5% Idling reduction</td>
</tr>
<tr>
<td><strong>Procurement</strong></td>
<td>-50% Avoid heavy &amp; strong passenger vehicles – check fuel efficiency rating!</td>
<td>-11% Aerodynamics tractor-semi trailer optimisation</td>
</tr>
<tr>
<td></td>
<td>-35% Full hybridisation (valid for inner city driving – less than 10% for</td>
<td>-5% Vehicle ancillary loads reduction</td>
</tr>
<tr>
<td></td>
<td>intra-city/extra urban)</td>
<td>-5% Vehicle weight (aluminium or high grade steel)</td>
</tr>
<tr>
<td></td>
<td>-7% Start’n stop automatic - microhybrid</td>
<td>-3% Low rolling resistance tires</td>
</tr>
<tr>
<td></td>
<td>-5% Vehicle ancillary loads reduction</td>
<td>-3% Super single tires</td>
</tr>
<tr>
<td></td>
<td>-4% Low rolling resistance tires</td>
<td></td>
</tr>
<tr>
<td><strong>Maintenance</strong></td>
<td>-10% Air filter check &amp; replacement</td>
<td>-10% Air filter check &amp; replacement</td>
</tr>
<tr>
<td></td>
<td>-3% Tire pressure control (on average)</td>
<td>-4% Proper engine tuning</td>
</tr>
<tr>
<td></td>
<td>-4% Proper engine tuning</td>
<td>-2% Low friction motor oil</td>
</tr>
<tr>
<td></td>
<td>-2% Low friction motor oil</td>
<td>-3% Tire pressure control</td>
</tr>
</tbody>
</table>

Even if the savings might not be added it is clear from the table that savings surpassing 10% should not be an issue applying the RECODRIVE approach.
7. Preparing your car for a fuel-efficient ride

This handout enumerates tips how to reduce fuel consumption when preparing for a ride.

7.1. Get rid of the garbage in the car

Passenger Cars

The rolling resistance and the acceleration losses directly relate to the vehicle weight: 100kg less saves 0.3 l/100km. Since air drag is lower at lower velocities, check if you might remove:

- Snow chains in summer
- Goods you do not need to deliver in the actual trip
- Heavy hydraulic car-jacks
- Full size replacement tires in city operation
- Bull bars
- Bicycle or ski racks
- Roof racks

If feasible and possible you might think about lighter replacement parts. Aluminium rims (may save 15kg) and additional fuel containments out of plastic are standard, lighter exchange seats might be in future if homologation may be achieved. If you add special painting over the existing, you also add weight (at minimum 1.5kg). You might also check for lighter stereo equipments (which may save 1.5kg).

Last, but not least, driving around with full tanks is also detrimental and may be the biggest saving in terms of weight reduction in operation. Only removing seats in minivans with seven or more seat might catch up with that.

G. Cebrat, FGM
Buses

Buses do not have the same possibilities as passenger cars saving weight during operation, most saving possibilities apply for ski buses operated also in summer, where the racks might be demounted.

Trucks

Think about the need of carrying around empty pallets, heavy lifting equipment, connecting rods etc. Logistics may also improve the kilometres for reverse logistics (pallets etc.).

7.2. **Anything fixed on your car increasing drag?**

Passenger Cars

By using roof-mounted racks you are increasing the cross-sectional area and the drag coefficient. By using rear mounted racks you are increasing the drag coefficient.

For trucks the gap between cab and load compartment is creating additional aerodynamic drag. It goes without saying that the absence of a deflector is a bad mistake and the deflector position is important. It should be adapted to the height of the compartment/container.
Figure 47 Comparison of bad and good truck roofs

For semi-trailers inflatable elements are closing the gap. When moving faster the semi trailers should be pressurized. Open trailers with small cross-sectional area of the load do not need deflectors, but tractors with small cross-sectional areas do.

Figure 48 Exchange of tractors would benefit the fuel efficiency

7.3. Check the tire pressure

For trucks you may save 0.4% per PSI which equals 6.9 % per bar under inflation (at least 5%). For passenger cars 0.5 bar may cause 15% more fuel consumption.
There are other factors you might check when measuring the tire pressure, for example unequal wear which might be caused by wrong toe, camber and caster.

When lifting one axle badly aligned axles or tires are not contributing to drag as well as dragging brakes.

**Figure 49 Liftable axle**

When lifting the vehicle and spinning wheels dragging brakes may be also detected.
7.4. **When did you check filters/exhaust mufflers last time?**

Air filters have increased pressure loss when running in dusty environments over a longer period of time. Some makes have pressure loss indicators.

![Figure 50 Pressure loss indicator for air filters](image)

Blocked exhaust mufflers also reduce efficiency. Dirt may decrease cross-sectional areas of air and exhaust piping and increase losses.

7.5. **Are there leakages or deficiencies increasing energy consumption?**

Especially with buses or trucks you might check for air leakages in the pressurised air system which keeps the compressor running for a longer period of time.

![Figure 51 Pressurized air system](image)

Apart from leaks, worn out pumps or compressors contribute to losses as well as damaged pressure keeping systems actuating the safety valve.
7.6. **Do belts or clutches have slip?**

Relative motion is slowed down by friction. Friction produces heat which is deducted from the mechanical power creating losses. Check the tension of the V-belts.

![Figure 52 V-belts](image)

Anti slide systems (traction control) in operation indicate that energy is lost at the interface between tire and road.

7.7. **Do you know the most fuel efficient route?**

Navigation aids may help you saving up to 15%.

There are other strategies - take the first parking lot and walk the rest, avoiding longer searching trips.

Last, but not least choosing the right velocity for being just in time may also save fuel.

7.8. **Are all covers tightly fixed?**

Especially with trucks, but also with roof mounted luggage with cover, it is important to have it tightened. Loose tarpaulins may increase fuel consumption by 10%.
Figure 53 Areodynamic roof rack covers

Tarpaulins should be tightened before starting your trip. The following method using ratchet tie-down fasteners is preferred.

Figure 54 Wheel covers - side impact protection
8. Driving your car efficiently

This handout lists the rules how to reduce fuel consumption while driving.

8.1. Avoid drag - reduce power demand

Reduce speed!

With a 1500kg gasoline powered vehicle with 130 km/h you have 6.5 l/100km consumption of the drag, with 160 km/h you would have 1.86 times the consumption equalling 12.12 l/100km for the air drag only. Thus amounts to a total of 15.6 l/100km instead of 10 l/100km. So avoid having too close dates. Good planning may avoid speeding if you already know the anticipated driving time and start in time. Modern trip computers may show you the effect of reducing speed on arrival and consumption – so you may decide.

Figure 55 OBU shows velocity influence on fuel consumption

Most important is to check when you will be awaited and discharged not to waste fuel when driving too fast.

Close windows at higher speeds!

Open windows increase the drag significantly – if the A/C is on the consumption is increased even further if the ambient temperature is higher.

Also switch off consumers like air condition, power amplifier, fans, window heating and seat heating and ventilation, if possible.
8.2. Strategic Operation (Driving in a Platoon)

Expanded scope of action

Anticipate traffic, drive smartly: Keeping safe distance and carefully watching traffic, driving becomes more fluent and fuel-efficient. As there is more time for decisions and less pressure, you will feel safer and more relaxed. If you drive 100 km/h you need a distance of 50m avoiding unnecessary braking if the predecessor has to reduce speed.

Figure 56 Distance to keep

In city traffic the bigger distance may benefit your driving even further, if you are lucky and hit the traffic light later after it turned to green. With hybrid vehicles part of the braking energy is regenerated, but of course only part.

With buses and a vehicle location system you know whether you are in time or ahead of schedule. If you are ahead of schedule of course you may allow the vehicle more to roll (coast). But even if you are not in time, there are situations where it does not help driving at higher speeds. Especially with red traffic lights or longer congestion queues it is very likely that the situation is the same whether you let the vehicle roll (coast) or not. So when you accelerate until the forced stop the velocity over time looks like that:
Sometimes the situation has even improved and you may use the energy which is stored in the movement of the vehicle. You will not believe it, but by approaching slower you might be faster on average when you manage to avoid the still stand. This then looks like this:

This way you save:

- Acceleration to full velocity
- Added drag at higher velocities
- Acceleration to velocity avoiding the still stand

In total this may save well more than 30% of the energy demand of the operation.
8.3. **What is the consumption per km in still stand?**

**Avoid idling!**

The consumption in still stand is infinite, because your distance travelled is zero. With a warm engine you may stop it even for 10 seconds. There are special stop’n start variants you may buy, if you are driving frequently in cities.

![Image of a car stopped]

With buses and frequent stops the consumptions is 1.4 l/h accounting to up to 7% of the overall consumption. Prepare your working environment as driver before starting the engine. A cold idling engine reduces the lifetime.

**Is hot soak an issue?**

With modern cars emissions are trapped but the balance depends on its capacity and efficiency. Avoid parking a vehicle with a full tank in the sun – you risk spills.

---

10 Suggestions to limit city bus idling Brian Hearing
Check your peace of mind!

There is a good correlation between your ability to avoid emotions and your fuel consumptions. Sometimes you cannot avoid, if others embarrass you, but by remembering this problem before the trip you might overcome it.

Do not take offending actions personally. Do not look into the eyes of aggressive drivers. Sometimes it is better to ask for excuse or thank the others. Do not use the horn unless there are risks.

When using the mobile phone, even if you have a hands-free equipment, you are distracted and make driving mistakes consuming more fuel than necessary.

8.4. Reporting of energy related problems

Returning to the depot you should report deficiencies. Power loss is possible caused by obstructions in the exhaust muffler, air filter or in the fuel system. If the vehicle drags to one side may be toe or pressure is the cause.

8.5. Drive at high torque and low to medium RPM

With most engines the best efficiency is achieved with higher torques and medium RPM at the same time. But do not misinterpret this as high power since the power is the product of both torque and angular speed.
If you compare driving at constant speed for different gears you get the following chart:

**Figure 57 Engine efficiency map**

**Figure 58 Comparing gears with two velocities**
For gasoline/petrol engines 2000 RPM are a good value, for newer vehicles it might be even lower.

![Graph showing optimum RPM range](image)

Driving within the “green revs area” at approx. 2000 r.p.m. leads to maximum fuel economy. The rev counter enables to save fuel and money and is benefiting the environment at the same time.

**Figure 59 Optimum RPM**

In city operation you may save up to 40%. The savings with higher speed depend on the kind of 5th gear you have – it should be an eco gear not allowing max. speed.

![Graph showing fuel saving potential](image)

**Figure 60 Fuel saving potential with gear shifting**
It is important to drive the engine at higher torques when accelerating, the engine management detects problems with regards to stalling and reduces your torque requirements- no damages whatsoever are to be expected.

8.6. The whole Ecodriving picture

You should have an eye on:

- Excess weight, which is carried around without any purpose
- Roof deflectors, which are not adapted to the container or load height
- Under inflated tires
- Small load factor

Some hidden problems require in-depth analysis like:

- Axle misalignment
- Tire toe-out
- Dragging brakes
- Low oil grade
- Clogged air filters
- Leaking pneumatic systems

Gear shifting not only affects the fuel consumption when accelerating. It also helps to decelerate with a higher (longer) gear, because then the fuel supply is stopped with most (modern) engines. Summarizing this gives the following rules for ecodriving.
**Eco-driving Operations for Passenger’s Car**

- **Methods of Pressing on the Accelerator Pedal**
- **Methods of Adjusting Speed**
- **Deceleration Without Waste**
- **Idling Stop**

**Speed**

- **Starting and Accelerating**
- **Cruising**
- **Decelerating**
- **Stopping**

**Time**

- **When Starting and Accelerating**
  - Accelerate taking around 5 seconds to reach 20km/h.
  - Conduct further acceleration smoothly.
- **When Driving**
  - Drive while watching in front, and maintain a wide space from the car in front to prevent changes in speed.
- **When Decelerating and Stopping**
  - Remove your foot from the accelerator early, and endeavor to drive stably.
- **When Stopped**
  - Engage neutral gear, and use the side brake.
  - If possible, eliminate idling by stopping the engine.

**Figure 61 Ecodriving tips**

Acceleration may be more powerful with ecodriving, so the engine operates in more efficient areas. This also means that with some gear boxes and more powerful engines (which we do not recommend) there is no time using all gears. Shifting from the first into the third gear might be useful under those conditions.

If your car has external oil heating check if, it is working before departing.
8.7. **Reduce ancillary consumption**

With increased comfort you do not only add weight to the vehicle, but also consume electric or mechanical power during operation.

If you **start from the shade** with open windows you may pre-cool your vehicle. But shut the windows as soon as you put your A/C on.

Also power amplifiers consume more at higher volume. Do you really need seat heating or the ventilating fan switched on?
9. How maintenance may improve fuel efficiency

The technical condition of the vehicle is an essential factor, it influences the effective consumption, the fuel expenses and hence the emissions. Obligatory official testing, decreasing taxes and the price of insurances for new vehicles are stimulating the renovation of fleets. But the official testing relates mostly to safety issues, we concentrate here on efficiency related issues. This handout describes the influence maintenance has on the fuel consumption while driving.

Maintenance has approximately the same influence on fuel consumption as driver behaviour.

You might set up a checklist depending on the time the vehicle is on the road and its purpose:

<table>
<thead>
<tr>
<th>Check</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dragging brakes (spinning the wheels)</td>
<td>In case of reported incidents, else infrequent</td>
</tr>
<tr>
<td>Tire and axle misalignment (tire wear)</td>
<td>Infrequent</td>
</tr>
<tr>
<td>Oil check (engine, gearbox, differential...)</td>
<td>Engine frequent, rest infrequent</td>
</tr>
<tr>
<td>Check filters (clogged air filters, dampers, catalyst...)</td>
<td>Frequent</td>
</tr>
<tr>
<td>Visual check aerodynamic improvements (tires, underbody, deflector...)</td>
<td>Frequent</td>
</tr>
</tbody>
</table>
9.1. **Brakes**

Depending on their type brakes might have contact and brake even when not in operation. Spinning the wheels will help to detect this.

9.2. **Axle misalignment**

Especially with multiple axles in buses or trucks axle misalignment causes additional drag.

Figure 62 Axle misalignment

9.3. **Wheel related: Tire pressurisation, Toe, (Camber and Caster)**

Apart from axle misalignment wheels are subject to wear and tear.

Tire pressure is important, but major deviations in toe also contribute to significant increase in fuel consumption. Diagnosis of the tire wear might reveal toe and improper inflation.
Figure 5: Toe, Camber and Caster

Figure 63 Toe, camber and caster

Also one tire toe out is possible when hitting an obstacle.
A tire producer quantifies the influence of toe on the fuel consumption with 20% which is higher than the influence of the tire pressure in this example.
<table>
<thead>
<tr>
<th>normal</th>
<th>Usual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unterluftdruck</td>
<td>Low tire pressure</td>
</tr>
<tr>
<td>Neu</td>
<td>New</td>
</tr>
<tr>
<td>TWI</td>
<td></td>
</tr>
<tr>
<td>Fahrtbeginn</td>
<td>Start of the trip</td>
</tr>
<tr>
<td>Nach (15 min)</td>
<td>After (15 min.)</td>
</tr>
<tr>
<td>Verschleißanzeiger</td>
<td>Wear-indicator</td>
</tr>
</tbody>
</table>

**Figure 65** Tire producer showing influence on tires

Driving with winter tires in summer may also cause 25% increase in fuel consumption and put you at risk due to reduced grip.

**Power train**

Torque converter having malfunctioning lockup are reducing fuel economy.

If you service passenger cars with powerful motorisation check whether you may restrict the top speed. With some engines the operation is too fuel rich at higher loads exceeding the standard emission tests. This fuel rich operation leads to additional fuel consumption.

Electric power trains may have direct propulsion without gears. Here we have low efficiencies with high loads at low RPM.
Buses

**Summary: Start-up process**

- Start generally using the 1st gear
- No gas when starting (at EDC)
- Drive at middle rotation speed until the engine is warm
- Accelerate continuous to your trip velocity

Avoid unnecessary startings by foresighted driving

**Figure 66 Tips accelerating**

You should commence the acceleration without your foot on the throttle. If you have a non synchronized gearbox, try to find the right RPM for shifting the gear without the need to adapt the RPM stepping on the throttle.

For automated gear shifting same applies as without it - keep distance to your predecessor.

**Summary: clutch and gearbox**

**Gearbox:**

- No gas when starting
- Starting with 1st gear
- No double-clutch, but rotation speed adjustment

**Manual transmission:**

- Drive on middle rotation speed using the highest possible gear

**Semi-automatic system**

- Do not totally rely on the electronic transmission – foresighted driving is not possible with it

**Automatic transmission**

- Drive in stick position D whenever possible
- Use kick-down only under exceptional circumstances
Avoid kick-down, if possible.

9.4. **Oil quality info**

Oil quality is essential for the service life time and the efficiency at the same time. Specialists say that oil quality should be adapted to the operation. If you drive short distances in cold climates viscosity may be higher. Oil diluted with water are not good lubricants, also metal particles are detrimental. Migrating to better oil qualities makes sense, especially in low load high RPM operation:

**Fully Synthetic Oil qualities Characteristics:**

- 0W-30 enhances engine performance and power
- 0W-40 ensures engine is protected from wear and deposit build-up
- 5W-40 ensures good cold starting and quick circulation in freezing temperatures, gets to moving parts of the engine quickly.

Depending on the main temperature of the operation, in case of short operation, choose an oil quality which is suited for lower temperatures.

*Figure 68 Motor oil choice*
Lower viscosity is generally risky, even if it helps with regards to fuel efficiency; newer oils are using polymers avoiding those problems.

However, with external oil heating you may further save fuel reducing friction in the starting period.

9.5. Cleanliness Heat Exchangers A/C

If the main heat exchanger and the oil heat exchanger of the engine are obstructed the average engine temperature is raised. This may have a negative influence on the efficiency. Same applies to the air cooler which might lead to lower air mass flow and furthermore to lower power.

With A/C heat exchanger higher temperatures caused by fouling increase energy demand.

9.6. Leakages Pneumatic System

If compressed air leaks out, energy for the compression is wasted. This may also be caused by damaged pressure control and actuation of the safety valve.

9.7. Filter / Exhaust Muffler Check

Lower engine power might be caused by obstructed air filter and/or exhaust muffler. Check for additional pressure loss which might reduce efficiency.

9.8. Spark Plugs

Used spark plugs reduce the ability to ignite the mixture without residues. It goes without saying that unburned fuel is a waste. The spark plug should look like this:

Figure 69 Good spark plugs
This is a worn out plug, which should be replaced.

Figure 70 Worn out spark plug

Short distance driving may cause a picture similar to the one with a too rich mixture.

Figure 71 Rich mixture with spark plugs

Please notice that not all problems with sparks may be seen from the outside, regular changes are mandatory or monitoring the fuel consumption.
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