It goes without saying that motor cars are very common and widespread in our society.

As a result, they are inevitably going to have a strong influence on our society’s sustainability through energy consumption, greenhouse gas emissions and unintended social impact.

At the same time, let us not forget that road transport has very positive economic and social benefits to our society.

This resource provides figures for some major quantifiable issues and points out other relevant factors. It explores the role that engineers can have in this topic.

This is the outline for the rest of the resource: some of the most important issues relating to energy consumption, greenhouse gas emissions, and unintended social impacts of road transport. It proceeds to outline both technical and social solutions. The key issue is that road transport is so widespread in our society - and so strongly woven into our lifestyles - that they inevitably have an enormous impact.
Between 1970 and 2005, transportation has grown to account for more than a quarter of the overall UK energy consumption, from an original 15%. (Total energy consumption has grown from 210.1 MTOE to 234.9 MTOE. In the same period, the population has grown from 54.83 million in 1970 to 59.7 million in 2005.
The decrease in energy consumption by the industrial sector is mostly due to the decline of industry in the UK during this period.
Similar data for the US can be found at the Department of Energy website. For example, the tabular data for energy use by sector http://www.eia.doe.gov/emeu/aer/txt/ptb0201a.html
Transport energy consumption has almost doubled between 1970 and 2004, whereas the population has only increased from 54.83 million to 59.7 million.
The largest increase has been from air transport, which has more than tripled since 1970.
Energy consumption from rail and water transport has fallen this 34 year period by 25% and 34% respectively, whereas consumption from road transport has almost doubled.

The primary energy source for rail includes coal, electricity and petrol.
Road transport includes passengers and freight.
The primary energy source for water includes coal and petroleum.

Population data available on-line from UN Dept. of Economic and Social Affairs http://esa.un.org/unpp
UK Road Traffic has increased 8-Fold in the last 50 years, there are 31.2 million registered vehicles, but overall road length has only increased by a 25%.

Cars and Taxis account for the majority of road traffic. (But not necessarily fuel consumption! Freight and commercial transport typically consume more fuel per kilometre. They also have greater impacts on air quality, accidents and infrastructure wear and tear. Annual vehicle kilometres of this category is represented by the delta between the two curves).

Motor vehicles travelled 490 billion km in 2003 in Britain
There are 31.2 million licensed vehicles in Britain (up from 9 million in 1962)
But the overall road length in Britain has only increased by a quarter in the last 40 years, to 392,000km

Similar information for the US is available from the Department of Transport www.dot.gov, or for example http://www.infoplease.com/ipa/A0004727.html
This chart show the evolution in UK transport usage by mode between 1970 and 2000.
Note that Cars, Vans, and Taxis are on a scale that is 10x the other modes.
Usage is given in "passenger kilometres" which factors in passenger density.
The distance travelled by bus fell by 25% between 1970 and 2000.
Passenger kilometres from motorcycles and pedal cycles are at similar levels to 1970, with the slight boom in motor cycle use enjoyed in the early 1980s having disappeared by 2000.
Rail passenger kilometres increased by 31% between 1970 and 2000.
But travel by cars, vans, and taxis dominates the UK transport usage, having double between 1970 and 2000.
Domestic Air transport passenger kilometres have almost quadrupled during the 30 years shown.

Consumer Demand

• Travel time budget: research shows that the mean time travelled per day is independent of income. Worldwide it is 1-1.5 hours.

• Likewise, around the world a person devotes on average 10-15% of their income to travel.

• Trend shows that as GDP/capita increases, passenger kilometres travelled increase. Therefore, growing economies demand ever higher speed transport.

These projections are based on a model designed to predict long-term scenarios. It has been determined that on average, fixed budgets of time and money are devoted to travel. (Time travel budget and money travel budget data is given in reference). That means that as income rises, so does the amount of spending on travel. Levels of future mobility depend on population estimates. The World Bank 1992 projections estimate an increase in world population to 10.1 billion in 2050. Growth is strongest in developing countries which account for 85% of the world population by 2050.

A fixed travel time budget requires that the mean speed of travel increases in proportion to the projected rise in total capita mobility. There may be an increase in luxury travel as travel budget increases. As traffic congestion becomes greater, people will adjust when they travel and where they live. Businesses will also change where they are located. For more details, see reference.

**CO2 Emissions by Transport Mode**

- **kg CO2 per passenger km**

- Small <1.4l petrol car
- Medium 1.4l-2.1l petrol car
- Large >2.1l petrol car
- Average petrol car
- Small <2.0l diesel car
- Large >2.0l diesel car
- Average diesel car
- Rail
- Air long haul
- Air short haul

Numbers extracted from the DEFRA “Guidlines for Company Reporting on Greenhouse Gas Emissions”.

# CO₂ Emissions by Transport Mode

## Fuel Life-Cycle Energy Consumption and CO₂ Emissions for urban transport modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>Seats</th>
<th>MJ per vehicle km</th>
<th>kg CO₂ per vehicle km</th>
<th>MJ per seat km</th>
<th>Grams CO₂ per seat km</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Train</td>
<td>300</td>
<td>117</td>
<td>11.7</td>
<td>0.39</td>
<td>3</td>
</tr>
<tr>
<td>Diesel Train</td>
<td>146</td>
<td>74</td>
<td>8.8</td>
<td>0.50</td>
<td>0</td>
</tr>
<tr>
<td>Light Rail</td>
<td>265</td>
<td>47</td>
<td>10.1</td>
<td>0.18</td>
<td>38</td>
</tr>
<tr>
<td>Underground</td>
<td>555</td>
<td>122</td>
<td>26.0</td>
<td>0.22</td>
<td>46</td>
</tr>
<tr>
<td>Single Deck Bus</td>
<td>49</td>
<td>14.2</td>
<td>1.6</td>
<td>0.29</td>
<td>33</td>
</tr>
<tr>
<td>Double Deck Bus</td>
<td>74</td>
<td>16.2</td>
<td>1.9</td>
<td>0.22</td>
<td>26</td>
</tr>
<tr>
<td>Minibus</td>
<td>20</td>
<td>7.1</td>
<td>0.8</td>
<td>0.36</td>
<td>40</td>
</tr>
<tr>
<td>Medium-Sized Car</td>
<td>5</td>
<td>3.5</td>
<td>0.39</td>
<td>0.70</td>
<td>78</td>
</tr>
</tbody>
</table>

**Road transport makes up around 21% of total man-made CO₂ Emissions in the UK**

(RAC Report 2003)

This table provides further insight into CO₂ emissions by urban public transport modes, including a "medium-sized car" for comparison. These figures include the "per seat" figures built into the transport mode.

In general, the slower forms of public transport using lighter vehicles consume less energy and produce the least CO₂ emissions.

The Underground appears to have high CO₂ emissions per seat km, but this is because (a) the system is old and (b) the figure is normalised by the number of seats, only, and does not include the standing capacity which makes a significant difference.

Data is from empirically compiled information Carpenter, Potter, and Roy, Potter and Yarrow.

Carbon dioxide emissions from road transport in Britain in 2001 were 31 million tonnes with emissions per vehicle having fallen from 1.08 tonnes per vehicle in 1993 to 0.95 tonnes in 2001. Road transport makes up around 21 per cent of total man-made carbon dioxide emissions in the UK. (RAC Report 2003)


CO₂ emissions are a direct function of the amount of petrol consumed

The plot is based on data for 6818 popular car models in the world market. Data courtesy of Granta Designs from their "Cambridge Eco-Selector" database. An educational version is available.

It shows Fuel consumption (miles/gallon) vs. CO₂ emissions (grams/kilometer)

"Combined" refers to combined cycle fuel economy rating, "CO₂ rating" refers to CHECK THESE WITH MIKE ASHBY!!

Note that all Greenhouse gases are converted to CO₂-equivalent using appropriate conversion factors, similar to what is shown in LINK TO CLIMATE CHANGE RESOURCE.

There is a strong correlation between fuel economy and GHG emissions.
In a typical motor car’s life, the **Use Phase** (driving and maintenance) dominates energy consumption at 85%. This is typical of **durable goods**. The average car in OECD countries lasts for 13 years and travels 120,000 miles.

Energy use in the Production, Manufacture and End-of life-management phases are relatively low because of 2 reasons:

1. Energy use is dominated by fuel use in the driving phase
2. Mass production of motor cars (since Ford’s production of the model-T) has greatly improved the energy efficiency of the car-manufacturing process.

Data source for diagram: [http://www.grida.no/climate/ipcc_tar/wg3/100.htm](http://www.grida.no/climate/ipcc_tar/wg3/100.htm)

Data Taken From: Bouwman & Moll (1999)
Between 1980 and 2004 there were dramatic improvements in automobile technology and thus greatly improved engine efficiency. However, this was focused towards making the cars larger and better performing rather than reducing fuel consumption. Data based on US Environmental Protection Agency data for “light vehicles”.

Does the big difference in petrol tax between Europe and the US partially explain the difference in private car ownership: 450 cars/1000 people in EU and about 700 cars/1000 people in the US?

The motor vehicle has a very beneficial role in society, too. To curtail its negative impacts (such as fuel consumption, GHG emission, and social costs due to accidents) requires society to enact policy. One of the most favoured and effective policy tools governments have at their disposal is taxation.

Intelligent transport systems such as timed entry freeways and on-board traffic directors could reduce congestion and increase the mean speed of automobiles by 15%.
• New technologies may come to market first in China

• In 2005, China has six of the world’s ten most polluted cities.

• The market for replacing batteries in electric bicycle with fuel cells is likely to be the earliest to be commercialised.

In China, things might be different, as problems of air quality, a desire to lead in a new technology, lower power requirements for vehicles as eight speaker stereos and air conditioning are not demanded, and the need to build a new infrastructure for fuelling, make fuel cells somewhat more attractive.

China’s two main cities, Beijing and Shanghai, have been selected by the Global Environment Facility (GEF) of the World Bank for the Fuel Cell Bus Demonstration Project. Under this project, the GEF will sponsor the deployment of six fuel cell buses and one hydrogen filling station each to both Beijing and Shanghai.

China’s National Development and Reform Commission (NDRC) has issued a new Automotive Industry Development Policy. The new policy, that became effective on June 1, 2004, stipulates that average fuel consumption of new cars should be reduced by 15% by the year 2010.

Public and private investment in fuel cell development in China over the next few years is projected to be over (US)$500 million.

The market for replacing batteries in electric bicycles is expected to be the earliest market to be commercialized, followed by buses.

Approximately 1 million buses were produced in China in 2002. This was an increase of 25% over production in 2001.

Under China’s fuel cell roadmap, more than 100 buses will have been tested under demonstration projects between 2005 and 2010. More than 1000 fuel cellpowered buses will be utilized in regular bus operations between 2008 and 2020.

The annual alternative fuels market in China is projected to grow from $75 million in 2002 to $1.8 billion by 2008.

Source: http://ecoworld.com/Home/Articles2.cfm?TID=352
Summary

• Road Transport impacts the environment by consumption of non-renewable fossil fuels and emissions, society by unintended consequences

• Road transport is also hugely beneficial to society and the economy

• As engineers, solutions include social systems (public transport) and technological improvements (hybrid cars, engineering for sustainable design).
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