APPENDICES
Appendix A - Ecoefficiency in automobiles

This text shows the calculations which support the discussion of eco-efficiency as an issue of the current light vehicle mobility paradigm, in section 2.1.2 of the main thesis.

Example of energy use within a conventional car: rough calculation.

Assume one average UK car: the Ford Focus conventional 1.6 litre gasoline saloon has a mass of 1300kg (UKTow.com, 2011). CO₂ emissions targets and figures can be used unmodified here as this is very close to the EU average mass, around which CO₂ emissions regulations are based (EC, 2009).

Assume one average UK adult as the driver, mass 77kg (NHS, 2009). Assume no passengers, as 60% of all UK journeys are solo (DfT, 2009a), rising to 85% for daily commuting (DfT, 2009b).

First the energy efficiency:

The Carnot Cycle thermodynamic efficiency of a typical modern gasoline engine is about 32% (Helle-Lorentzen, 2007) – this is the proportion of available energy which can be recovered from burnt fuel (and the laws of physics give combustion engines an extreme theoretical upper limit of something like 45%). Typical diesel engines are slightly better at about 35% (MacLean and Lave, 2003) but, as will be seen, this does not make a very large difference. The rest of the energy is lost mainly as exhaust heat to the surrounding environment, and a smaller amount as heat to the coolant (Heywood, 1988).

Using a previous Ford summary of data for the 1.6 litre gasoline engine (Helle-Lorentzen, 2007), the engine’s output is further dissipated in losses at idle (about 8% of the original fuel energy), in the transmission and driveline (1.5%), and the alternator and accessory drives (3%). This leaves 32% minus 12.5% -or approximately 20%- of the original energy for actually moving the vehicle. Next aerodynamic drag must be overcome, using another 11%, leaving roughly 9% of the energy finally for accelerating and decelerating. As drag cannot be avoided (although it can be reduced) and so can be assumed to be part and parcel of the activity of driving the vehicle around, we shall use this 20% figure.

Now the mass ratio:

The ratio of masses in the occupied car is 77:1300 (kg) and so the driver represents about 6% of their combined mass. Effectively this means only 6% of the remaining 20% of the original energy -or about 1% of the original energy- is moving the person about, and performing the primary purpose of the vehicle- “personal mobility”.

If we assume 4 adults in the car their mass at 308kg would be about 24% of the combined system and this original energy efficiency would still only rise to a mere 5%.

It can be seen from the above that there are limits to how much energy efficiency can be improved. Technological advancements such as energy recovery and more efficient choice of motive power (e.g. in hybrids) help but do not usually constitute a large change. On the other hand there are many vehicle designs which offer mobility, from bicycles weighing
considerably less than their rider to jet aeroplanes weighing thousands of times more. The mass ratio for cars is quite large for private, unshared transport as used by most citizens. Public transport is bigger and heavier but can also be more efficient, whilst –if designed as a system correctly- carrying more people and so the mass ratio is also reduced. Note that this is a European example– regions with less efficient, heavier cars are worse and ones with lighter more efficient ones better. Hence there is an argument that the greatest gains in personal mobility should come from breaking the paradigm of the 5-seater 1.5 tonne vehicle, capable of 150mph and several hundred miles (and therefore carrying heavy extra equipment to allow this), moving one person at lower speeds and ranges.

Appendix references

Appendix B- Question set used in initial internal Ford interviews
(A very similar set of questions was used with external interviewees).

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<th>Name</th>
<th>Job Title &amp; Grade</th>
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General scene setting & background questions:
Q0 What degree background do you have?
Q1 How long have you been working in the automotive industry?
Q2 Which other sectors have you worked in as well?
Q3 How long have you worked for Ford?
Q3 And how long in this kind of job?

Easing into the specific questions:
Q4 What is your experience of how the company makes decisions?
Q4b What do you understand to be the decision-making process?
Q4c What is your general role within decision-making?

Q5 Are there differences in your view between how Ford makes daily/detailed decisions and high level/longer range (strategic) ones?
Q6 How are you involved in higher-level or long-term decision-making? (Proposer, participant, decision owner etc)
Q7 How do the high-level / longer range decisions relate to daily and short-range ones?
Q10c How do strategies get made, and adjusted or discarded within Ford?

Q8 Are you aware of a company definition for what constitutes a ‘strategic decision’?
Q8b How would you define a strategic decision, and are there significant differences between your definition and what you believe the company’s definition to be?

If they believe they are involved in strategic decision-making:
Metrics/Information focus:
Q9 What sort of factors do you consider when making more strategic decisions?
Q9b Which factors is it most useful to consider? (Why?)
Q9c Is there anything included which is unhelpful? (Why?)
Q9d Is there any missing information which you think would be useful? (Why?)
Q9e How far ahead in time is considered?

Methods focus:
Q10 What standard approaches, if any, are used in decision-making?
(to arrange information, analyse it, compare options, present recommendations etc)
Q10b What approaches do you feel might be appropriate but which are not currently used?

Focus questions (only if sustainability, resilience and risk don’t come up earlier):
Q11 How do you come across sustainability- in the wider meaning of environmental impact- within these decisions?
Q11b Ditto sustainability- in terms of social impact?
Q11c Ditto sustainability- in terms of economic sustainability?
Q11d And what about organisational resilience? (The capacity to absorb shocks, keep functioning and adapt).

Q12 Is there anything else important that you’d like to include about decision-making at Ford?

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Appendix C- Question sets used in case studies
(These were used with participants in case studies 3-5 and the training studies).

Pre-case study questions
This set was used to discover the current practice before the case study took place.

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<tr>
<th>Name</th>
<th>Job Title &amp; Grade</th>
</tr>
</thead>
</table>

| Location/firm | Date |

The purpose of this interview is to find out about you, about the sort of strategic studies you do, and also about how you will do or are doing a particular study right now. This is so that we can later identify what, if any, changes occur to what you do, discover and experience, when SuReSDS is used within or alongside your study.

General scene setting & background questions:
Q0 What degree background do you have?
Q1 How long have you worked in the automotive industry?
Q2 Which other sectors have you worked in?
Q3 How long have you worked for your current firm?
Q3 And how long in this kind of job?

Study-process general questions:
Q4 What is your experience of how the company generally conducts strategic studies (process & culture, any tools)?
Q5 What is your general role within this? (Proposer/champion, participant, decision owner; solo analyst or team member, team size etc.)
Q6 Thinking about the study you are doing now/ about to do, do you have any particular method in mind for how you would normally approach this?

Q7 Are there any methods normally used which are unhelpful, and why?
Q8 Are there any methods missing which would be helpful, and why?

Study-specific questions:
Q9 Is the study strategic (e.g. early, conceptual or high level decisions about product/service systems, new design features, business models, regional activities etc)?
Q10 Does it contain a sustainability question or element? -usually a social or environmental aspect as well as economic and technical ones.
Q11 Does it contain a resilience question or issue? –in the sense of creating robust business cases and models or designs/ performance in some other sense.

Q12 What sort of factors (information, data, judgements) would you usually consider when carrying out this particular study?
Q13 Which ones is it most useful to consider? (Why?)

Q14 Is sustainability (in the wider social/environmental/economic sense) mentioned explicitly in the study brief?
Q15 Is resilience of any kind mentioned explicitly in the study brief?

If there is an existing previous or current study:
Q16 Are there any types of information included which are unhelpful? (Why?)
Q17 Are there any missing kinds of information which you think would be useful? (Why?)

Back to general questions on the study:
Q18 How far ahead in time is being considered?

Q19 Do you have any particular expectations or beliefs at this point about trying SuReSDS as a tool in this situation, and if so what are they?

Q20 Is there anything else important that you’d like to include?

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**Post-case study questions**

These were used after the case study had occurred, to discover what effect if any use of SuReSDS™ had created. In the training case studies only the training-specific questions could be answered.

**Name**

**Job Title & Grade**

**Location/firm**

**Date**

The purpose of this interview is to find out about your experience of using SuReSDS, and also what, if any, changes occurred to what you did, discovered or concluded, within or alongside your study as a result; and whether you plan to change how you do future studies.

**Training-specific questions:**

Q1 Did the training session provide the right level of information on the SuReSDS approach?
Q2 If not, what could be improved and how?
Q3 Did the examples to be worked help you to become familiar and comfortable with SuReSDS?
Q4 If not, how could these be improved?
Q5 Please indicate any other feedback on the training, good or bad:

**Analysis-specific questions:**

Q6 Did you use SuReSDS as a solo analyst or in a team environment?
Q7 If in a team, what was your role?
Q8 Did you, in your view, interact with the Research Engineer as (tick all that apply):
   - A full team member
   - A facilitator
   - An occasional source of extra information
   - An observer
   - Other (please give details):

Q9 Was SuReSDS used to (please choose one):
   - Analyse existing data from a recent study
   - Analyse data in parallel with a current study
   - Analyse data within a current study

(show SuReSDS process flow)

Q10 How easy or hard was the process to use?
Q11 Could you carry out all the steps effectively? If not, please provide more detail on why and what might improve this.
Q12 Did you need to move back and forth/ cycle around the process, did it flow linearly, or did something else happen?
Q13 Were you able to create satisfactory results using this approach?
Q14 Will you be able to use the results in future within your current study, and what for?
Q15 Which new pieces of information were created or discovered in the process?
Q16 Did they affect the way the analysis was done or the conclusions that were drawn?
Q17 Which new steps or techniques did you find useful, if any?

Q18 Would you use the approach or even some elements again, and if so for what?
Q19 Were there any types of information or processes included which are unhelpful? (Why?)
Q20 Were there any missing kinds of information or processes which you think would be useful? (Why?)
Q21 Do you think this approach could be used more widely at your company? (how, why?)

Q21 Did the experience of using SuReSDS meet your expectations or beliefs? (How and why?)

Q22 Is there anything else important that you’d like to include?
Appendix D - Example Teachable Point of View (TPoV) slides

6 Paradigms of Sustainability - Values

- **VSS**: very strong sustainable (natural capital must be improved to restore the ecosystem)
- **SS**: strong sustainable (natural capital must be maintained)
- **WS**: weak sustainable (capital managed for humans with some limits)
- **WE**: weak exploitation (human and natural capitals can be traded-off)
- **SE**: strong exploitation (human economic benefit more important)
- **VSE**: very strong exploitation (very short-term economic focus only)

Sustainability is only represented by SS & VSS paradigms. Choice between these two depends on ecosystem status.

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The Nine (known) Planetary System Boundaries

- 9 bio-physical planetary systems are vital to human survival, and until recently have been stable
- Staying within the limits of ALL 9 processes provides the only “safe operating space” for humans

<table>
<thead>
<tr>
<th>Process</th>
<th>Parameter</th>
<th>Limit (current)</th>
<th>Boundary Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen cycle (considered one system with Phosphorous)</td>
<td>N₂ removed from atmosphere for human use (Mt pa)</td>
<td>35 (121)</td>
<td>Massively Exceeded. Agricultural &gt; natural N; eutrophication of systems</td>
</tr>
<tr>
<td>&amp; Phosphorous cycle</td>
<td>Amount of P flowing into oceans (Mt pa)</td>
<td>11 (8.5-9.5)</td>
<td>Just within limits, rising. Causes ocean extinctions</td>
</tr>
<tr>
<td>Biodiversity loss</td>
<td>Extinction rate (per Million species per year)</td>
<td>10 (&gt;100)</td>
<td>Strongly Exceeded. Erodes ecosystem resilience</td>
</tr>
<tr>
<td>Climate change</td>
<td>Atmospheric CO₂</td>
<td>350ppm (387)</td>
<td>Exceeded. (both) Rising. Drives non-linear change</td>
</tr>
<tr>
<td></td>
<td>Radiative forcing (W/m²)</td>
<td>1.0 (1.5)</td>
<td></td>
</tr>
<tr>
<td>Ocean acidification</td>
<td>Global mean saturation of aragonite in sea water</td>
<td>2.75 (2.9)</td>
<td>Just exceeded, rising</td>
</tr>
<tr>
<td>Ozone depletion</td>
<td>Concentration (Dobson)</td>
<td>276 (283)</td>
<td>Just exceeded, falling</td>
</tr>
<tr>
<td>Global freshwater use</td>
<td>Human use (km³ pa)</td>
<td>4,000 (2,600)</td>
<td>Within limits, rising</td>
</tr>
<tr>
<td>Change in land use</td>
<td>% land used for crops</td>
<td>15 (11.7)</td>
<td>Within limits, rising</td>
</tr>
<tr>
<td>Atmospheric aerosol loading</td>
<td>Concentration in atmosphere</td>
<td>TBD</td>
<td>?? Unknown</td>
</tr>
<tr>
<td>Chemical pollution</td>
<td>E.g. endocrine disruptors</td>
<td>TBD</td>
<td>?? Unknown</td>
</tr>
</tbody>
</table>

5 of 9 exceeded or badly so. This is unsustainable long-term, implying VSS approach is required to restore these systems.
Revised Sustainability Framework

Be “Strong” to survive

“Strong” sustainability- nested systems
- Impossible to have a human society outside the planetary environment
- The economy is only one subset of human society
- Human activity is large enough to have a significant effect on the planetary ecosystem and resources
- Recognises system constraints

The amount of energy and physical resources available on the Earth over a given period is fairly fixed. Some resources are very limited (fossil oil, rare earths). But some resources are much larger than the planetary systems seem to need (iron and silica are relatively plentiful, for example).

Economic activity exists within human society & the natural ecosystem

So- What is affected? – “Capitals” view

We have 4 kinds of resource or “capital”- like 4 bank balances. Using a Product-Service view:

Manufactured Capital- created by humans mostly for humans
- Consumable, short-lived, and long-lived goods
- Manufactured (product related) services (shelter, mobility, communication, etc.)

Natural Capital – occurs without human intervention (but also with it)
- Living resources (e.g. plants or animals)
- Non-living resources (e.g. minerals, tidal energy)
- Ecosystem services (e.g. food, shelter, air, rain, other natural cycles) for humans and other species

Human Capital- as perceived by human beings
- Material wealth (including access to or ownership of goods; virtual and real money)
- Wellbeing (physical health, mental state, societal participation etc.)
- Human services (labour, skills, behaviour etc.)

Moral/Ethical Capital – as defined by human society/culture
- Explicit moral structures (e.g. laws & sanctions)
- Implicit moral structures (e.g. cultural norms and expectations, sanctions)
- Organisation and/or Brand ethical capital (reputation which grants “license to operate”)
- Ethical “services”- societal license for organisation to function?

For “strong” sustainability these must be balanced to keep the planetary systems -and company- healthy. ALL the capitals have value for humanity and thus its economy.
Impacts of Idealised Activity (business) on Capitals

Capitals are affected by all activities. Currently other capitals are consumed and rearranged via human activity to create human benefits, and manufactured assets. Ideally we might want a business activity to try to enhance all capitals (or at least provide bigger benefits than degradations).

Business activities ideally create human benefits whilst maintaining or increasing other capital levels. Is this possible?

Impacts of Current Business-As-Usual on Capitals

Capitals are affected by all activities. Currently other capitals are consumed and rearranged via human activity to create human benefits, and manufactured assets. Long term this is unsustainable, if other assets are exhausted & degraded by the impacts of this activity and their feedback loops. Impacts are cumulative.

Currently industry (inc. Ford) mainly depletes capitals to benefit wealth & wellbeing of some humans. Improvements are possible!
Impacts of Current Business-As-Usual on Capitals

Contention:
- Over time humans (customers) will value ‘Very Strong Sustainability’ – VSS- activities more (ethical expectations)
- As feedback effects demonstrate the survival impacts of long term unsustainability, people’s paradigms will shift down through the levels in Maslow’s hierarchy of needs

Therefore:
- Any human activity (incl. businesses) needs to understand and manage its impacts
- Which feed back long-term into its capitals (resource) inputs
- And ideally produce human wellbeing and wealth, without depleting resources beyond the limits required for continued human and other species (ecosystem) survival

Impacts and vulnerability to resources need adjusting to ensure continued activity (company existence)

Are There Boundaries for Business Too?

Remember: the economy is a subset of human society, which is in turn within the planetary environment. So, all 9 planetary systems & limits will affect businesses by affecting humans, and other resources directly or indirectly.

But:
- Some will be affected more than others (vulnerability) by each system
- Some will adapt better than others (resilience)
- Some impact the limits more than others (unsustainability)

Survival is digital- you either do or you don’t survive*.  
*Krause, 2011

You can however take measures to improve your chances:
- assess your worst vulnerabilities to (resource) hazards
- design both your organisation and products to be resilient to these
- reduce your worst unsustainable impacts
- choose balanced, positive (best) impacts where possible

Resource resilience and (un)sustainability set boundaries for Business too
Resilience for Businesses: definition

Resilience: Adaptation to hazards whilst operating and growing
- Limited resources
- New technology
- High costs
- Competitors
- Infrastructure
- Customers
- Large market changes
- Business Models
- New risks
- Commodity shortages

Company

Evolution to sustainable business – only one opportunity to succeed?

Effective Sustainability needed by ~2050 or earlier
- because impacts are cumulative
- if you do not improve now, you’ll have a bigger task later

Why do Sustainability and Resilience both matter?

1) Business as usual is unsustainable and leads to extinction
2) Resilience widens range of survivable operating conditions in short term, but does not avoid extinction
3) Survival requires improvements in both Sustainability and Resilience

Event Horizon: Stay above to survive

Organisations are “buffeted” by signals and noise. Direction of travel or buffeting can push them into extinction.
Definitions

**Resilience**: ability of a system to return to stability of function after disruption, continue to function and adapt to environmental changes

**Strategic resilience (of companies)**: using this ability to generate sustainable competitive advantage

**Irresilience**: (company) vulnerability to sources of disruption, which may lead to its function ceasing

**Sustainability (of an activity)**: ability to continue long-term; the goal of maintaining or improving the wellbeing of environmental, social and economic resource bases

**Sustainable development**: process of delivering this via human society

**Unsustainability**: negative impacts of an activity on resource bases, which may lead to its function ceasing through feedback effects from its own and others’ activities

Both concern company continuation and eliminating vulnerabilities or feedbacks which prevent this