Appraisal of Sustainability

Environment Indicators

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1. Introduction

This report describes the methodology for and outcomes of a study to identifying and validate a set of environment indicators of sustainable development for transport. The work has been undertaken in parallel with a similar process for the social and economic pillars of sustainable development, as identified in the Brundtland definition. The research represents the first stage of a two-part project seeking to develop an improved methodology for capturing and assessing the sustainability of decisions about, or that impact on, the transport system.

There already exists a substantial literature and policy base which forms the basis for a set of indicators relevant to quantifying the environmental elements of the sustainability of transport. Two principal definitions of sustainable development were used, in line with those employed across the whole project:

1. The Bruntland definition:
   "*Economic and social development that meets the needs of the current generation without undermining the ability of future generations to meet their own needs*" (WCED, 1987)
2. The European Council of Ministers on Transport definition:
   "*Limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation and uses non-renewable resources at or below the rate of development of renewable substitutes while minimizing the impact on land and the generation of noise*" (ECMT, 2001)
3. The 2005 UK Sustainable Development Strategy:
   "*Living within environmental limits*" (DEFRA, 2005) which also builds on the 1998 Sustainable Development Strategy "*effective protection of the environment and prudent use of natural resources*" (DETR, 1998)

2. Methodology for indicator selection

This section describes the method taken in selecting the indicators of environmental progress.

2.1 Areas of focus

The first stage of the investigation identified six key categories of environmental quality that would be investigated based on the definitions set out in Section 1. These were:

- Pollutant Absorption Capacity
- Resource Efficiency
- Direct impacts on health
- Local quality of life
- Land take
- Water Quality

2.2 Development of indicator list

An initial indicator list was developed which included all indicators where transport could be said to have a significant impact on the absolute value and likely future direction of change. Key data sources included UK Government Statistics and Eurostat. Policy documents, European Union directives and on-doing research programmes were all reviewed to ensure that the full range of issues had been addressed at this initial filtering stage. The sub-sections below provide an indication of the breadth of the coverage of the search.

2.2.1 Pollutant Absorption Capacity

The UK transport appraisal guidance (WebTag) notes that transport can affect the following pollutant related phenomenon over large areas (in addition to those related to local air quality which are covered below in direct impacts on health).

- acidification;
- excess nitrogen deposition; and
- generation of tropospheric ozone" (Section 3.3.2)

Another high profile area to be considered is climate change where the EU member states will collectively reduce emissions by 8 per cent below 1990 levels by 2008-2012; In 1998, the EU member states agreed to redistribute the EU's target and, as a result, the UK's target is to cut its greenhouse gas emissions by 12.5 per cent. The basket of six greenhouse gases are CO_2, CH_4, N_2O, PFC, HFC and SF_6.

2.2.2 Resource Efficiency

One of the overall aims of the 1999 UK sustainable development strategy was to make prudent use of natural resources, i.e. to do more with less. The ECMT definition goes beyond the need to be more efficient over time by suggesting rates of change of renewables and non-renewable energy use. In selecting a set of indicators, we wished to avoid specifying solutions and therefore chose to focus our efforts on the selection of indicators that are representative of less resource intensive travel.

A substantial literature exists that enables the total material resource requirements to be calculated for the construction, use and disposal of all products (e.g. Spangenberg et al. (1998) and Bartelmus (1999)). In some approaches, efforts are made to convert the resource requirements to an equivalent area of land to determine the extent to which the levels of resource use are consistent with depletion and equity principles. Pearce (2000) reviews a range of concepts for examining resource use and concludes that "It is easy to be sympathetic to the concerns that have produced notions like environmental space and ecological footprints. They quite rightly emanate from concerns about equity. In so far as they remind us yet again that raising resource efficiency is paramount, they are helpful. Unfortunately, beyond this they have little or no relevance for policy." (p29). He goes on to suggest that the key concept is improving the efficiency of resource use. "There is one common

feature to all policy guidance approaches considered in the previous section: they all conclude that improving resource efficiency is important in varying degrees" (p32)

2.2.3. Direct impacts on health

Two principal environmental impacts were adjudged to have a direct impact on health. First, local air quality which can have a variety of impacts, particularly on asthmatics, those suffering other respiratory diseases and those suffering heart disease. It is estimated that over 40,000 deaths are brought forward each year as a result of poor air quality. "The Air Quality Strategy (AQS) for England, Scotland, Wales and Northern Ireland (DETR, 2000) set objectives for eight key air pollutants to protect health with achievement dates between 2003 and 2008. In 2000/01, the objectives for three of the pollutants were reviewed with more stringent targets being set and an objective for a ninth pollutant was introduced (DEFRA, 2003). It is expected that achieving objectives for ambient concentrations of NO2 and PM10 will be more challenging than for the other pollutants. The AQS objectives are equivalent to or more stringent than the mandatory EU limit values so achieving the objectives will ensure that the limit values are achieved" (Webtag Unit 3.3.3).

Secondly, accidents have a direct impact on health and are often featured under listings of environmental impacts.

2.2.4 Local Quality of Life

This type of measure is best developed from a bottom-up approach as it is highly related to the environment within which the question is posed. It is difficult to imagine the same indicators being relevant to a run-down inner-city area as would apply to those around a national heritage site for example. The Audit Commission Quality of Life indicators have been through several iterations and have resulted from substantial community engagement. It would therefore appear likely that these offer a good representation of issues of general concern to people's quality of life. These were therefore reviewed.

A further indicator of local quality of life is noise disturbance from all forms of transport.

2.2.5 Land Take

The nature of the indicators selected for land take relate to the interpretation of policies relating to land-take. Should the policy objective for sustainable development be to minimise absolute land-take (irrespective of the importance that people might place on different sorts of land or of the impacts of such an approach) or to minimise and mitigate against the damage or use of any land with important natural capital.

2.2.5 Water Quality

Transport also affects water quality through surface run off, or in the case of maritime direct emissions into water courses (EPA, 200x).

2.3 Criteria for selecting indicators

At all stages of the project it has been important to select indicators that would be useful in the ex-ante evaluation of projects by decision-makers. The indicators put forward therefore had to be clear and unambiguous to decision-makers. For example, one of the more commonly used sustainability indicators in the UK transport sector is transport intensity – the increase in kilometrage for every unit increase in GDP. Over time, there has been shown to be a 'decoupling' of kilometrage with GDP growth as shown in Figure 1 (along with energy intensity). However, traffic intensity does not say whether the decoupling is sufficient to put us on a track to a sustainable future and, as currently framed, excludes aviation kilometres (which when included presents a markedly different trend from decoupling!). In addition, GDP estimates for local areas are rarely made, rendering this unsuitable for the local scale.

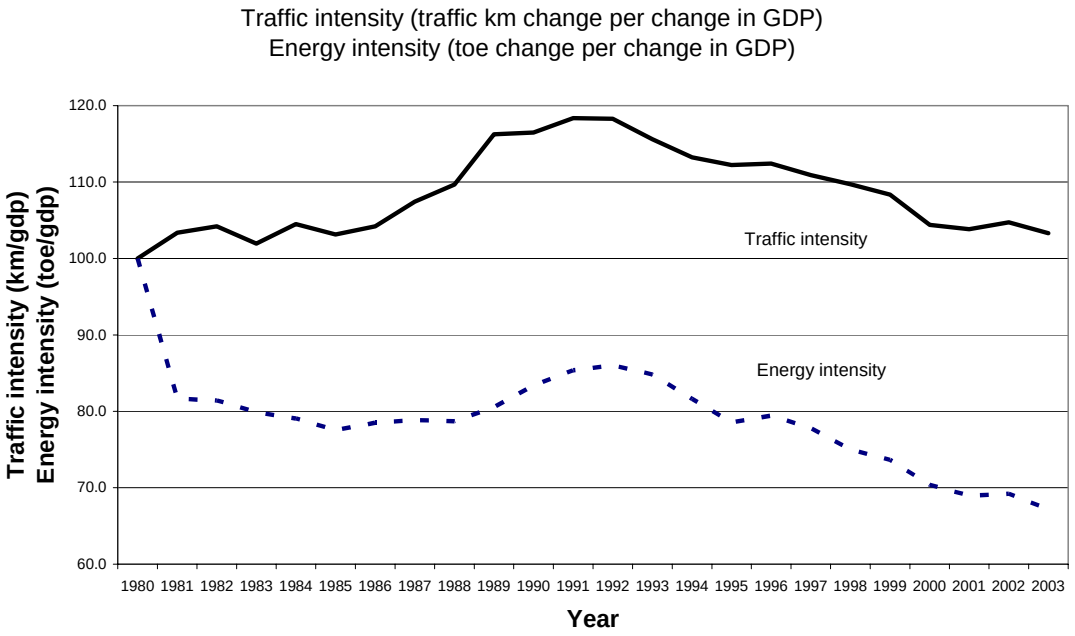

Figure 1: Changes in traffic and energy intensity from transport 1980-2003

It was also felt to be important that the number of indicators presented to decision-makers be limited to make it possible for decision-makers to meaningfully process and compare the information presented for competing options. It was necessary therefore to review the extent to which transport contributed to the environmental issue concerned. If the contribution of transport was of relatively small magnitude compared to other sectors then it was decided to exclude the indicator from the analysis. It would, for example, have been possible to include all six of the pollutants from the greenhouse gases listed in Section 2.2.1. Carbon dioxide emissions form around 85% of the UK's total contribution to the basket of climate change gases (based on carbon dioxide equivalence conversions). Transport contributes around one-third of all CO_2 emissions making the selection of CO_2 as the key indicator of progress the most logical conclusion.

2.4. Initial list of indicators

Table 1 below shows the initial list of indicators considered on the basis of the literature review and filtering process set out above. Section 3 describes the list of indicators that were proposed for the stakeholder consultation and presents the rationale for their selection.

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Table 1: Initial indicator set

Aspect of Sustainable Development	Areas of interaction between transport and environment	Possible Indicators	Comments
Limits **emissions** within the planet's ability to absorb them	Toxic emissions from vehicles	1. Absolute SO_2 emissions 2. Annual and winter mean SO_2 levels above 20 µg/m^3 3. Absolute NH_3 emissions 4. Absolute NO_x emissions	1. 585 thousand tonnes by 2010 EU National Emissions Ceiling Directive 2. National air quality strategy vegetation protection. Not suitable for scheme appraisal 3. 297 thousand tonnes by 2010 UNECE 4. 1,167 thousand tonnes by 2010 EU National Emissions Ceiling Directive Note the Audit Commission QoL indicator 27 (only PM10 moderate and high, annual average NOx concentration and rural sites for ozone (moderate or high).
	Greenhouse gas emissions from vehicles	1. Absolute CO_2 emissions	1. 20% domestic CO_2 reduction by 2010 compared to 1990, 60% by 2050. The Audit Commission QoL indicator 28 is CO_2 emissions by sector and per capita
	Water pollution from transport	1. WebTag water quality indicators	Not picked up as an Audit Commission QoL indicator. The life cycle analysis work shows that heavy metals from production and recycling are the most important contributors but are relatively limited (Castro et al.).
needs of individuals, companies and societies to be met **safely** and in a manner consistent with **human** health	Accidents and loss of life resulting directly from transport	1. Total number of injury accidents 2. Total number of KSIs	Audit Commission QoL indicator 10 is for all accidents. These correspond to LTP mandatory indicators.
	Health impacts resulting indirectly from transport	1. Exceedences of air quality objectives (NO_x and/or PM_{10}) 2. the gap (time) between the recommended amount of daily exercise and that currently achieved	Audit Commission QoL indicator 27 (PM10 moderate and high, annual average NOx concentration and rural sites for ozone (moderate or high).
	Impairment of quality of life resulting directly from transport	1. Number of residences exposed to aircraft noise above 57 LAeq,T 2. Number of residences exposed to noise above 55dBA	Further consideration may be required for rail noise exposure thresholds.

Minimises impact on land	Direct impacts of infrastructure on land-take	Qualitative environmental capital score from Webtag (7 point scale)	A total land take indicator would be possible. The only current land-use indicator of relevance relates to the % of housing built on brownfield sites.
	Indirect impacts of supporting infrastructure on land-take	-	
Minimises generation of noise	Noise generated by vehicles	See earlier section on impacts of noise on quality of life	There has to be a rationale for noise reduction which is related principally to annoyance levels. There may be some arguments for peace in the countryside also.
Limits **waste** within the planet's ability to absorb them	Wear and tear repair of vehicles	Total use of non-renewable resources by transport CO_2 emissions per private car trip CO_2 emissions per capita CO_2 emissions per tonne-km Energy use per private car trip Energy use per capita Energy use per tonne-km	The life cycle analysis literature suggests that over 90% of the impacts are from in-use. Energy use in construction and maintenance is however important and should be included in total energy use measures. It seems sensible to focus on in-use impacts except where the purchase of a vehicle is foregone. The concept endorsed by a whole range of approaches (Pearce, 2000) is the enhancement of resource efficiency.
	Scrappage of vehicles		
	Wear and tear repair of roads		
Resource use (renewables and non-renewables)	Use of renewable energy in travel		
	Use of renewable resources in vehicle construction		
	Use of non renewable energy in travel		
	Use of non renewable resources in vehicle construction		

3. Discussion of selected indicators

3.1. Proposed indicators

Table 2 below shows the first set of indicators that were developed and discussed with a range of external stakeholders. The remaining sub-sections of this chapter explain in more detail the rationale for selecting these from the larger list in Section 2.

Table 2: Indicators presented to key stakeholders

Area of Progress	Indicator of Progress	Disaggregation	Direction of change
Pollutant Absorption Capacity	Total CO_2 emissions	-	Down – 20% cut by 2010 compared to 2000 levels and 60% by 2050
	Total NO_x emissions	-	Down – UK total to be 1,167 thousand tonnes by 2010 EU National Emissions Ceiling Directive
Resource Efficiency	Total non-renewable energy by all transport	-	Down
	CO2 emissions per person-trip	Personal travel only	Down
	CO2 emissions per tonne-km	Freight only	Down
Direct impacts on health	Exceedences of air quality objectives (NOx and/or PM10)	At risk groups (e.g. % of people suffering Chronic Heart Disease)	Down (standards set for 2005 and 2010)
Local quality of life	Number of residences exposed to aircraft noise above 57 LAeq,T		Down
	Number of residences exposed to noise above 55dBA		Down
Environmental Capital	Qualitative environmental capital score (7 point scale)	Landscape Townscape Heritage of Historic resources Biodiversity Water Quality	Cumulative impact of policies neutral or beneficial

3.2. Pollutant Absorption Capacity

3.2.1 Total CO_2 emissions

Strength of indicator

Elevated levels of a 'basket' of 6 greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6) in the atmosphere resulting from human activity is widely accepted to contribute to global warming. CO_2 emissions are the dominant contributor to global warming for surface and air transport. The UK Government has a domestic goal to cut CO2 emissions by 20 per cent below 1990 levels by 2010. Further to this, the Energy White Paper of February 2003 put forward a longer term commitment to "put the UK on a path to reduce carbon dioxide emissions by 60 per cent by 2050" (DTI, 2003, p3).

Disaggregation

The indicator needs to be presented as a total for transport generated in the area concerned.

Direction of change

Total CO_2 emissions should fall over time. The total percentage reduction due to transport is not fixed. The review of the Climate Change Strategy due to be published in late 2005 should shed some light on the total sectoral contribution. There are further issues of regional and local contributions to this. The DfT's National Transport Model should provide some indication of the relative contributions of different parts of England.

Data source

Typically derived from vehicle kilometrage and speed figures combined with some assumptions on average fleet fuel efficiency.

Problems of measurability

Local variations in fleet fuel efficiency are rarely known. Local authorities tend to exclude kilometres travelled on the Highways Agency inter-urban network from their calculations.

3.2.2. Total NO_x emissions

Excess nitrogen deposition is a serious transboundary pollution issue. In 2003 the UK produced 1583 tonnes of which road transport contributed 762 thousand tonnes or 48.2% of total. The next largest sector is industry at 21.2%. The most stringent policy limit that has been agreed is the EU National Emissions Ceiling Directive which limits UK emissions to below 1,167 thousand tonnes by 2010.

Disaggregation

The indicator needs to be presented as a total for transport generated in the area concerned.

Direction of change

NO_x emissions should also fall over time although, in common with the CO_2 indicator, the relative contribution of different sectors is not set.

Data source

Typically derived from vehicle kilometrage and speed figures combined with some assumptions on the age and make-up of the fleet (petrol vs. diesel).

Problems of measurability

Local variations in fleet characteristics are rarely known. Emissions from vehicles are not measured (unlike local air quality) but rather estimated through models.

3.3. Resource Efficiency

3.3.1 Total non-renewable energy by all transport[1]

Natural resource depletion and efficiency is not explicitly captured through the NATA framework. It was not felt appropriate to specify the rates of renewable and non-renewable use as the framework should avoid specifying solutions that may distort policy making. No measure of the impact of the actual natural resources used (e.g. amount of aggregate) has been included. Approaches such as the ecological footprint and total material resource use were examined and rejected as they appear to have little direct policy meaning and are complex amalgamation indicators.

[1] inc. construction and maintenance of infrastructure and vehicles

Strength of indicator

As one of the aims of the UK sustainable development strategy is to make prudent use of natural resources, i.e. to do more with less a measure of total non-renewable energy use was felt to be a good measure of depletion. The indicator includes energy consumed in the construction and maintenance of both new infrastructure and vehicles which can be calculated using the notion of 'embodied energy'. However, it is worth noting that around 90% of energy from vehicles comes from the in-use phase (Castro et al. 2003) and (Schmidt et al. 2004)).

Disaggregation

This figure does not need to be disaggregated.

Direction of change

The amount of non-renewable energy consumed should be falling over time.

Data source

Embodied energy estimates are becoming more common place. However, there is currently no well established approach to calculating the embodied energy of transport interventions.

Problems of measurability

The absence of a robust methodology to include all aspects of the construction and recycling process makes the focus of this indicator more likely to be on the in-use phase at this stage which can be calculated from modelled assumptions (See CO_2 above) and measured directly through fuel consumption.

3.3.2.a CO_2 emissions per person trip (personal travel)

Strength of indicator

Despite the decoupling suggested to exist in Section 2.3, per-capita and per-trip levels of energy consumption continue to rise and overall energy use is not falling. Whilst it would be possible to adopt a per-km measure of energy use, average trips have continued to lengthen over time as more people drive so this too hides some important trends. A per-trip measure was felt to best capture the extent to which our activities rely on journeys that use energy.

Given the strong relationship between energy use and CO_2 emissions and the desire to estimate total CO_2 emissions, that it would be preferable to use CO_2 per trip rather than energy use.

3.3.2.b CO_2 emissions per tonne-km (freight)

Strength of indicator

A per-trip analysis for freight would not work given the complexity of movement of freight. Energy use (in this instance as above taken to be proxied by CO_2 emissions) per unit of freight moved is accepted to be a good metric of efficiency within the freight industry. The use of tonne as the unit of freight moved appears most suitable and is neutral across modes. Such an indicator would however be subject to change as a result of changes in the nature of the freight sector. Where, for example, there is a contraction in an energy intensive freight commodity it may make the sector appear better with no net intervention having been made and vice versa. The drawbacks of this approach are however compensated to some extent by the message that this conveys. If we move to a more energy intensive form of commerce then the efforts required to cut emissions become more important.

Disaggregation

The indicator for 3.3.2a and 3.3.2b do not need to be disaggregated further than already implied by splitting personal and freight travel. More disaggregate data will exist however (e.g. road, rail) from the calculations.

Direction of change

Both indicators should fall over time.

Data source

Typically derived from vehicle kilometrage and speed figures combined with some assumptions on average fleet fuel efficiency. Estimates of freight kilometres run will also be required.

Problems of measurability

Local variations in fleet fuel efficiency are rarely known. Freight calculations will be difficult, particularly for local areas which typically house only one small part of many freight trips and for whom the expense of collecting commodity movements may prove excessive.

3.4. Direct impacts on health

3.4.1. Exceedences of air quality objectives (NOx and/or PM10)

Strength of indicator

The Air Quality Strategy (AQS) for England, Scotland, Wales and Northern Ireland has set objectives for nine key air pollutants to protect health with achievement dates between 2003 and 2008. It is expected that achieving objectives for ambient concentrations of NO_2 and PM_{10} will be more challenging than for the other pollutants. Assessments also suggest that it is these two pollutants that are most at-risk of exceeding the objectives near major roads. The indicator is one of exceedences as the limits are set to protect those most at risk.

Disaggregation

It may be appropriate to further establish the extent to which the exceedences impact on the most at risk populations (e.g. those suffering from heart or respiratory problems and asthma).

Direction of change

The number of days of exceedences of air quality standards should fall, ideally to zero.

Data source

Vehicle emission estimates are, in larger cities, fed into air pollution dispersion and weather models to provide estimates of exceedences. However, for those cities without this capability, shorthand assessment methods are available based on traffic volumes from the Air Quality Management assessment section of the DEFRA website (www.defra.gov.uk).

Problems of measurability

Guidance is available through the AQMA website and there is a national emissions inventory, providing support at a 1km grid square resolution. Validation of models against actual air quality readings can be undertaken using data from the government's network of high precision pollutant sensors around the UK.

3.5. Local quality of life

3.5.1a Number of residences exposed to aircraft noise above 57 LAeq,T

Strength of indicator

For aircraft noise, 57 LAeq,T approximates the onset of significant community noise disturbance.

3.5.1b Number of residences exposed to noise above 55dBA

Strength of indicator

55dBA is the World Health Organisation recommended daytime limit level for dwellings. An survey by the Building Research Establishment estimated that 54 per cent of the population in the UK is exposed to levels above this. The noise metric used is $L_{A10,\ 18\ hour}$ for road and $L_{Aeq,18\ hour}$ for rail, consistent with Webtag guidance. The indicators could be further adapted to reflect the new EU noise mapping directive which proposes new day and night noise metrics.

Disaggregation

It is possible to disaggregate further by income group but this is not current practice.

Direction of change

This should fall over time.

Data source

Noise models can be applied for both road and air transport. The Department of Transport publishes guidance on how to do this through its website. The EU requirement for noise mapping means that noise estimates should become more straightforward to produce in the coming years.

Problems of measurability

Noise is monitored around airports and this can be used for validation purposes. Less systematic collection of noise from road traffic occurs.

3.6. Environmental Capital

3.6.1. Qualitative environmental capital score

Strength of indicator

Webtag describes the development of the environmental capital indicators. The approach covers Landscape, Heritage of Historic Resources, Biodiversity and Water Environment and was developed by the statutory environmental bodies (Countryside Agency, English Nature, English Heritage and the Environment Agency) in co-operation with DfT. “The four main elements of the approach are:

- to describe sequentially the characteristic environmental features being appraised;
- to appraise the environmental capital, using a set of indicators, by assessing:
    - the importance of these characteristic features;
    - why they are important and to who; and
    - their inter-relationships with other environmental attributes;
- to describe how proposals impact on the environmental features, including effects on its distinctive quality and substantial local diversity; and
- produce an overall assessment score for the Appraisal Summary Table (AST) on a standard textual seven point scale (Slight, Moderate or Large Beneficial or Adverse, plus Neutral). “ (Webtag Unit 3.3.6)

Disaggregation

Landscape, Heritage of Historic Resources, Biodiversity and Water Environment

Direction of change

Adverse impacts, particularly moderate and large, should be avoided. Positive impacts would be seen to build up environmental capital and be consistent with sustainable development.

Data source

A variety of data sources are available through the statutory environmental bodies to assist in conducting these assessments.

Problems of measurability

The assessments are necessarily subjective. However, in line with the requirements of the Strategic Environmental Assessment, the process requires those developing new schemes and proposals to consider and to consider how to avoid or mitigate the impacts identified.

4. Stakeholder feedback

4.1. Stakeholder views

The stakeholders were generally supportive of the environmental indicators selected, accepting that the environmental side of sustainable development was generally more well developed than the social and economic aspects. Three principal queries were put forward:

- It was suggested that energy use should be adopted as the measure of resource efficiency rather than CO_2 emissions per trip or per tonne-km (T2000)
- Land is an environmental good of itself. For example, the Boston Big-Dig project has returned large areas of the city back to pedestrian and green public space usage. Could an absolute land take indicator be adopted? (SDC and T2000/CPRE).
- Does the framework capture cumulative impacts/benefits on the environment (and more generally) (DfT)?

4.2. Responses to stakeholder views

The following adjustments have been made to the framework in response to the issues raised by the stakeholders:

1. Resource use measures will be energy use per person trip and energy use per person kilometre.
2. Whilst the argument about an absolute land-take has some merit, the Webtag procedure appears to offer the most suitable route forward so no absolute land-take indicator is included.
3. A cumulative CO_2 emissions indicator will be added as the impacts from emissions of greenhouse gases last for periods commensurate with a typical project assessment of 30 to 60 years. Other 'cumulative' impacts can be derived by taking a suitable mid-point assessment if the pathway and the end-point are of particular importance and concern to a policy intervention.

5. Recommended revisions

The final list of environmental indicators is shown below in Table 3.

Table 3: Environmental Indicators

Area of Progress	Indicator of Progress	Disaggregation	Direction of change
Pollutant Absorption Capacity	Total CO_2 emissions	-	Down – 20% cut by 2010 compared to 2000 levels and 60% by 2050
	Cumulative Total CO_2 emissions	-	Down compared with existing annual rate played forward
	Total NO_x emissions	-	Down – UK total to be 1,167 thousand tonnes by 2010 EU National Emissions Ceiling Directive
Resource Efficiency	Total non-renewable energy by all transport	-	Down
	Energy use per person-trip	Personal travel only	Down
	Energy use per tonne-km	Freight only	Down
Direct impacts on health	Exceedences of air quality objectives (NOx and/or PM10)	At risk groups (e.g. % of people suffering Chronic Heart Disease)	Down (standards set for 2005 and 2010)
Local quality of life	Number of residences exposed to aircraft noise above 57 LAeq,T		Down
	Number of residences exposed to noise above 55dBA		Down
Environmental Capital	Qualitative environmental capital score (7 point scale)	Landscape Townscape Heritage of Historic resources Biodiversity Water Quality	Cumulative impact of policies neutral or beneficial

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