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Revision of Green Public Procurement Criteria for Road Design, Construction and Maintenance

Technical report and criteria proposal

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Abstract
GPP criteria for Road Design, Construction and Maintenance
The development of EU GPP criteria for Road design, construction and maintenance aims at helping public authorities to ensure that road projects are procured and implemented with higher environmental standards. The aim of this document is to provide details on the reasons for selecting these GPP criteria and references for further information.

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Abbreviations and Acronyms

AADT	Annual Average Daily Traffic
ADC	Average Degree of Curvature
ADP	Abiotic Resource Depletion Potential
AHWG	Ad Hoc Working Group
AM	Asset management
AP	Acidification potential
B	Build
BOQ	Bill of Quantities
BOT	Build, Operate and Transfer
C&DW	Construction and Demolition Waste
CEDR	Conference of European Directors of Roads
CEN	Comité Européen de Normalisation
CF	Carbon footprint
CMA	Cold Mix Asphalt
CPR	Construction Product Regulation
CRCP	Continuously Reinforced Concrete Pavement
D	Design
DAC	Dense Asphalt Concrete
DB	Design and Build
DBFO	Design, Build, Finance and Operate
DBO	Design, Build And Operate
DLPAC	Dual Layer Porous Asphalt Concrete
ECI	Early Contractor Involvement
EEA	European Environmental Agency
EIA	Environmental Impact Assessment
EMAS	Eco-Management and Audit Scheme
EoL	End of life
EP	Eutrophication potential
EPD	Environmental Product Declaration
EWC	European Waste Catalogue
Fc	Fuel consumption
GHG	GreenHouse Gases
GPP	Green Public Procurement
GWP	Global Warming Potential
HMA	Hot Mix Asphalt
HWMA	Half Warm Mix Asphalt
IRI	International Roughness Index
ISO	International Organization for Standardization
ITS	Intelligent Traffic Systems
ITT	Invitation To Tender
JPCP	Jointed Plain Concrete Pavements
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LCCA	Life Cycle Cost Analysis
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
M&R	Maintenance and Rehabilitation
MEAT	Most Economically Advantageous Tender
MPD	Mean Profile Depth
MSWI	Municipal Solid Waste Incinerator
NRA	National Road Authority
ODP	Ozone Depletion Potential
OECD	Organ. for Economic Cooperation and Develop.
PAC	Porous Asphalt Concrete
PAHs	Polycyclic Aromatic Hydrocarbons
PED	Primary Energy Demand
PED-NR	Non Renewable Primary Energy Demand
PED-R	Renewable Primary Energy Demand
PEF	Product Environmental Footprint
PFI	Private Finance Initiative
POCP	Photochemical Ozone Creation Potential
PPP	Public Private Partnership
RAP	Reclaimed Asphalt Pavement
RF	Rise and Fall
RUT	Rutting
SCL	Sight Class
SEA	Strategic Environmental Assessment
SMA	Stone Mastic Asphalt
SSM	Sustainable Supply Mix
TC	Technical Committee
TEN-T	Trans-European Transport Network
TSL	Thin Surface Layer
WFD	Waste Framework Directive
WLC	Whole Life Cost
WMA	Warm Mix Asphalt

1 Introduction

Public procurement constitutes approximately 19% of overall Gross Domestic Product (GDP) in Europe (EC, 2011) – and thus has the potential to provide significant leverage in seeking to influence the market and to achieve environmental improvements in the public sector.

To reduce the environmental impact of public purchasing, it is important to identify and develop green public procurement (GPP) criteria for products, services and works which account for a high share of public purchasing combined with a significant improvement potential for environmental performance.

The construction and maintenance of roads in an energy and resource efficient way is an important policy objective for Europe. The Roadmap to a Resource-Efficient Europe highlighted the significant impact of construction on natural resources.

The development of GPP criteria for Road design, construction and maintenance aims therefore at helping public authorities to ensure that road projects are procured and implemented with higher environmental standards. In order to identify the areas with substantial environmental improvement potential it is necessary not only to analyse the overall environmental impacts of roads but also to understand the most commonly used procurement processes for road construction and maintenance and to learn from the actors involved in delivering successful projects.

For this reason, the European Commission has developed a process aiming at bringing together both technical and procurement experts to develop a broad body of evidence and to develop, in a consensus oriented manner, a proposal for criteria delivering substantial environmental improvements.

Green Public Procurement (GPP) is a voluntary instrument that is defined in the Commission Communication "COM(2008) 400, Public procurement for a better environment" as "...a process whereby public authorities seek to procure good, services and works with a reduced environmental impact throughout their life cycle when compared to goods, services and works with the same primary function that would otherwise be procured.". Therefore, GPP criteria are to be understood as being part of the procurement process and thus must conform to its standard format. Hence, GPP criteria will be formulated either as Selection criteria, Technical specifications, Award criteria or Contract performance clauses which, according to the Buying green handbook (EC, 2011), can be understood the following way:

- *Selection criteria*. When assessing ability to perform a contract, contracting authorities may take into account specific experience and competence related to environmental aspects which are relevant to the subject matter of the contract. They may also exclude operators who are in breach of environmental law in some cases, and - for service and works contracts only - ask specifically about their ability to apply environmental management measures when carrying out the contract.
- *Technical specifications*. These constitute minimum compliance requirements that must be met by all tenders. They need to be related to characteristics of the work, supply or service being purchased itself – and not to the general capacities or qualities of the operator. It is also very important that they are clear, understood by all operators in the same way and possible to be verified.
- *Award criteria*. These can be used to stimulate additional environmental performance without being mandatory and therefore without foreclosing the market for products not reaching the proposed level of performance.
- *Contract performance clauses*. These specify how a contract must be carried out. For supply contracts, the main opportunity for the use of environmental clauses is often to specify how the goods will be delivered.

For each set of criteria there is a choice between two ambition levels

- *The Core criteria are designed to allow easy application of GPP, focussing on the key area(s) of environmental performance of a product and aimed at keeping administrative costs for companies to a minimum*.
- *The Comprehensive criteria take into account more aspects or higher levels of environmental performance, for use by authorities that want to go further in supporting environmental and innovation goals*.

It should be borne in mind that the procurement of roads is a particularly complex issue which necessarily results in the fact that, for both core and comprehensive levels of ambition, the inclusion of green criteria does require - when compared to standard solutions - increased expertise, verification effort and, at least for some of the criteria and depending on the procurement route and the experience of the design team and contractors, higher upfront costs.

This technical report provides the technical background information and further details on the rationale behind the proposed GPP criteria for Road design, construction and maintenance. The ultimate goal is to provide precise and verifiable criteria that can be used to procure roads with a reduced environmental impact throughout their life cycle. It is an updated version of the technical report prepared for stakeholder consultation prior to the 2nd Ad Hoc Working Group (AHWG) meeting that took place in January 2015 and includes the discussions had with stakeholders. Feedback has been collected during the 2nd consultation round (23 December 2014 - 22 February 2015) and through further written consultation of experts on specific sub-topics (maintenance definition, pavement-vehicle interaction, noise, durability and maintenance and rehabilitation strategies). This feedback has been included in the background rationale for each criterion. For clarity purposes, a summary has been added in some sections where several comments have been collected.

Accompanying this technical report are a preliminary report providing background information and a description of the factors underlying potential GPP criteria (which was prepared ahead of the 1st AHWG meeting that took place in March 2014), the GPP criteria document for Road design, construction and maintenance and a supporting guidance document (the *Procurement practice guidance document*) that provides orientation on how to effectively integrate these GPP criteria into the procurement process.

Publically available information related to the development of the GPP criteria for Road design, construction and maintenance can be found at (http://susproc.jrc.ec.europa.eu/road/) hosted by the Institute for Prospective Technological Studies IPTS.

1.1 Scope and definitions

Definition of road

A review of the main definitions used by relevant institutions was performed in order to set a unified definition for "roads". In line with the common definitions used by the Organisation for Economic Co-operation and Development (OECD) and Eurostat, it is proposed to define "road" by:

Line of communication (travelled way) open to public traffic, primarily for the use of road motor vehicles, using a stabilized base other than rails or air strips (Eurostat, 2009).

Classification of roads

The sources analysed set different classifications of roads, but there are shared classifications between Eurostat and the International Road Federation (IRF) as shown in the following table:

Eurostat	**IRF**
Motorway / freeway	*Motorways*
Express road	*Highways, main or national roads*
Road outside a built-up area	*Secondary or regional roads*
	Other roads – Rural
Road inside a built-up area: urban road	*Other roads – Urban*

The market analysis carried out in Task 2 of the project showed that the main source of market data is IRF, which provides the figures for the statistical pocketbook on transport published by the European Commission (EC 2013a). For that reason, it is proposed to use the IRF classification. It has to be mentioned that in these statistics "other roads (rural)" and "other roads (urban)" are aggregated in one class called "other roads".

Definition of road construction and road maintenance

The previous GPP criteria for Road construction and traffic signs defined "road construction" as "the preparation and building of a road using materials, including aggregate, bituminous binders and additives that are used for the sub-base, road-base and surfacing layers of the road". This definition is proposed to be retained in the framework of the current revision, but adding the comments received from the consultation related to the cement:

<u>Road construction</u>*: the preparation and building of a road using materials, including aggregate, bituminous and hydraulic binders and additives that are used for the sub-base, road-base and surfacing layers of the road.*

Roads are built in layers and three main types of road construction could be identified: <u>flexible pavements</u>, <u>rigid pavements</u> and <u>semi-rigid pavements</u> (Sherwood, 2001). See Annex 1

Road maintenance includes multiple and overlapping activities, and it is extremely challenging to find a universal definition and classification that could apply across Europe. In order to be consistent with the terminology used throughout Europe and following the suggestions of some stakeholders received during the consultation after the 2nd AHWG, the BEXPRAC study (CEDR, 2010a) is taken as reference. This study was carried out by 13 National Road Authorities (NRAs) in order to benchmark the performances of their maintenance and operation policy within the framework of the Conference of European Directors of Roads (CEDR). Taking into consideration the homogeneous way of defining life cycle cost actions introduced in this study, the following definitions are proposed:

<u>Road maintenance</u>: *all actions undertaken to maintain and restore the serviceability and level of service of roads* (PIARC Road Dictionary).

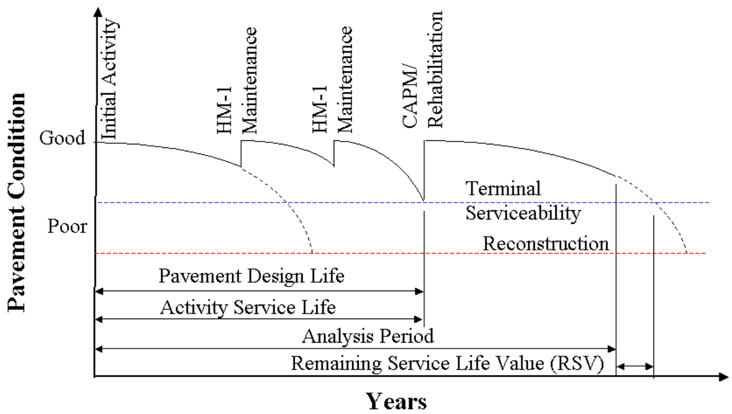
- <u>Routine maintenance</u>*: all operations which can be scheduled on a periodical basis with a view to maintaining a satisfactory level of service which is as close as possible to the initial state and in accordance with the classification of the road* (PIARC Road Dictionary).

- *Preventive maintenance and rehabilitation: work undertaken to* preserve or *restore serviceability and to extend the service life of an existing* road (PIARC Road Dictionary).

  Preventive maintenance is typically applied to pavements in good condition having significant remaining service life, without significantly altering the structural capacity, while rehabilitation takes place when the structural efficiency of the existing facility is compromised.

Road reconstruction: *work performed to upgrade the network or replace the entire road section* (CEDR 2013). From a procurement perspective, this phase is similar to the construction phase and therefore would be subject to a specific Invitation to Tender (ITT).

In Figure 1, an example of the evolution of road pavement conditions and the different maintenance activities is provided according to Caltrans (2013).



HM-1 major maintenance;
CAMP Capital Preventive Maintenance/ Rehabilitation

Figure 1. Scheme of maintenance activities (Caltrans, 2013)

For the purposes of this document:

- Routine maintenance actions are considered as those including activities such as crack sealing, pothole repair, minor correction of surface defects and minor shape correction for flexible pavements and joint sealing for rigid pavements. Winter service activities, maintenance of road signs and markings, maintenance of drainage appliances, vegetation maintenance, cleaning and inspections can also be included (CEDR 2013);
- Preventive maintenance is considered to include partial depth milling and resurfacing of surface and binder course for flexible pavements and of the surface course for semi-rigid pavements and thin overlays. In case of rigid pavements, it is considered to include activities such as renewing longitudinal joints, (micro)-milling, grinding, grooving, surface crack filling, strip-wise replacement. In the case of jointed plain concrete pavements (JPCP), filling cracks, dowelling and anchoring cracks and joints, repair of edge and broken off-corners, replacement of slabs are also included. In the case of continuously reinforced concrete pavement (CRCP) replacement of areas with punch-out are also included (PIARC, 2013);
- Rehabilitation is considered to include milling and resurfacing of flexible pavements, partially or fully including the structural layers, concrete slabs repairs of rigid pavements and structural overlays.

In the case of any specific ITT, the contracting authority is urged to clearly distinguish what they consider as routine maintenance, preventive maintenance and rehabilitation, within their maintenance and rehabilitation plan, since these may vary between different regions in Europe.

Scope proposal

According to the information gathered in the Preliminary report, it is recommended that the GPP criteria cover the following phases:

- *Materials production including raw materials extraction*. This phase consists of the processes needed to manufacture construction materials and products and includes the entire upstream supply chain needed to produce each material (for example extraction and production of aggregates and refining of crude oil for the production of bitumen). Transportation needed to move pavement materials to and from production facilities and to the project site are included in this phase. Transportation distances can vary widely based on project location. Off-site equipment used in the materials production is accounted for in this phase. Finally the employment of by-products, recycled materials and recovered waste materials is also included.

- *Construction*. This phase usually includes clearance of the construction site (removal of infrastructure and vegetation), earthworks including the possible construction of earth mounds, ground works including the stabilisation of the sub-grade, on-site equipment (as pavers, dozers, millers, etc.), construction of the pavement layers, construction and laying of the drainage and water run off systems and placement of road furniture. Analysis of congestion caused by the works is included.
- *Use.* This phase includes the daily traffic on the road pavement and thus vehicle fuel consumption during the road service life. It has to be considered that a pavement and its properties are only responsible for a fraction of the vehicle fuel consumption, namely those associated with its structural characteristics and surface texture (influencing the rolling resistance).
- *Maintenance (and operation).* This phase runs in parallel with the use phase, ending when the road is decommissioned. Some maintenance operations share the same materials, and hence impacts, with the construction phase. In detail, it typically includes routine maintenance (for example filling potholes in the surface and winter maintenance such as de-icing, road salting/gritting), periodic maintenance and rehabilitation, and substitution of lighting or road ancillary elements. Analysis of congestion caused by construction and maintenance is included.
- *End-of-life (EoL).* This phase can be applied to worn surface courses that are removed off-site during maintenance and operation activities or, in rare cases, when an entire road structure is decommissioned or replaced.

Finally, it has to be specified that noise has been included in the project scope, with noise reducing surfaces and noise abatement measures being therefore considered.

The scope proposal has been shaped according to the main European legislative requirements and standards. Analysis of existing or draft GPP criteria for Road design, construction and maintenance in various countries has also been carried out, *e.g.*, the Dutch GPP criteria on roads, the French voluntary commitment between the road constructor's federation and the Ministry, the draft Italian GPP criteria on road construction and maintenance and the Australian and United States rating systems.

A stakeholder suggested that also bridges and tunnels should be included in the scope proposal but construction technologies and methods vary among different infrastructures. Although it could be interesting to wider the boundaries of the study to include other kind of civil works and infrastructures, it is suggested that specific studies should be developed for different infrastructures, in order to better identify the main environmental impacts and hot spots of each.

Exclusions

During the stakeholder's consultation, a number of exclusions were suggested in questionnaire responses:

- Road markings;
- Street lighting and traffic signals;
- Traffic signs;
- Information systems;
- Foundations and lighting of traffic signs;
- Other types of road furniture (pedestrian walkways, bollards, overhead gantries and central reservations).

A significant share of road markings are paint products and for this reason they are included in the EU GPP criteria for paints, varnishes and road markings[1], currently under development.

1 http://susproc.jrc.ec.europa.eu/paints/. Once finalised, the criteria will be available here: http://ec.europa.eu/environment/gpp/eu_gpp_criteria_en.htm

The reason for the exclusion of street lighting and traffic signals is that these products are covered by separate EU GPP criteria[2]. Reference to the existing GPP criteria is made in the criteria proposal.

It was recommended that traffic signs including foundations are excluded from the product scope because traffic signs are of minor importance in the overall potential environmental impacts (Stripple, 2001; SUSCON, 2006; Loijos et al., 2013 – also see Chapter 3 'Technical and environmental analysis' of the preliminary report and Annex III Literature review of the supporting document of the preliminary report). This conclusion is in particular supported by the findings of Stripple, who calculated the approximate influence of the traffic signs below 1% of the environmental impact when considering only raw material extraction, construction, operation and maintenance. Traffic signs were also excluded from the Criteria for the Sustainable Public Procurement of Roads developed by the Dutch Ministry of Housing, Spatial Planning and the Environment in 2010 (NL Agency, VROM, 2010). Furthermore, traffic signs have not been considered in the Italian GPP criteria[3] for road construction currently under development.

Lighting systems consume relatively small amount of energy compared to the energy consumption through the full life cycle of a road. For example, according to Stripple (2001), during 40 years of service life of a local road, the total energy consumption of lighting is approximately 5% of the total energy consumption during the road life cycle. Typically, information systems are energy efficient and only use a small fraction of the lighting energy consumption, therefore these systems do not appear as one of the main hot-spots within the environmental analysis. However, considering that a holistic approach will be proposed, energy consumption and impacts from lighting could be included in the LCA analysis.

Foundations and lighting of traffic signs are of minor importance to the total environmental impact. Lighting of traffic signs are energy efficient and therefore use relatively small amounts of energy compared to the energy consumption through the full life cycle of a road (Stripple, 2001; Mroueh et al., 2001).

Based on a review of the literature, other types of road furniture (pedestrian walkways, bollards, overhead gantries and central reservations) are typically of minor importance to the total potential environmental impacts (Stripple, 2001). Given the diversity of roads, it is already challenging to develop usable and clear criteria for road pavement construction alone. Expanding the scope to road furniture would add further complexity to the criteria whilst only delivering comparatively small environmental improvements. Therefore it is recommended that these products are excluded from the EU GPP criteria for Road design, construction and maintenance.

The most dominant factors that affect the environmental impacts of a road during its service life will depend on the unique characteristics of each road. The choice of relevant environmental criteria will be related to those aspects of road construction that are identified as most relevant based on the LCA of different road types.

The initial approach of the scope proposal was to exclude some elements that seem to be less relevant in relation to the main environmental issues involved in road construction and maintenance. Notwithstanding, the output from the stakeholders survey shows a concern about these exclusions, and the consequent potential improvement that might be ruled out at this stage of the project. In order to achieve the broadest view of the sector, these elements were addressed in the technical analysis carried out in Task 3. Based on the findings from the literature review on LCA, these elements result in environmental burdens that do not reach the cut-off values considered in the studies, thus, they are not analysed within the boundaries of the system. As a consequence, none of the initially excluded elements were examined in LCA studies and therefore it is proposed to keep the exclusions suggested at the beginning of the project.

1.2 Market analysis

General economic indicators in the transport sector

Roads facilitate a very important mode of transport. In Europe, about 46% of goods transport and over 80% of the passenger transport occurs on roads. General turnover for road passenger transport and road freight transport is approximately 368 billion Euro in the EU-27 (data for 2009 from ERF; 2013), accounting for 32.4% of total turnover in the transport sector.

2 http://ec.europa.eu/environment/gpp/pdf/criteria/street_lighting.pdf

3 Personal communication

However, while growth in freight transport kilometres was reported as 5.3%, during the same period passenger transport kilometres were shown to drop by 1.0% (ERF; 2013).

The importance of the road transport sector is supported by employment data in Europe. In 2010, an estimated 2.93 million people were employed in road freight transportation and 1.93 million in road passenger transportation, accounting for around 46.5% of all employment in the transport sector (EC, 2013a).

General economic indicators for the construction sector in Europe

The construction sector is split into two main categories: "buildings" and "civil engineering work". Civil engineering works are subdivided into several categories and defined as: “construction not classified under buildings, for example railways, roads, bridges, highways, airport runways and dams” (EC, 2013b). The data presented in Figure 2 shows that "production for construction" in Europe is at its lowest level during the last 15 years (data from Eurostat, 2014).

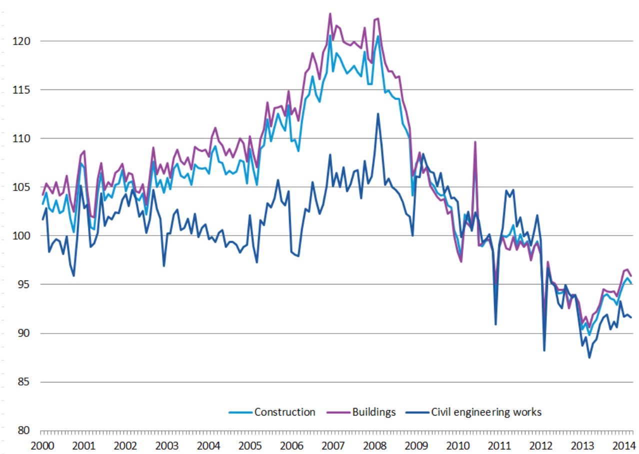


Figure 2: Index of price adjusted construction output, EU-28, 2000-14 (Eurostat, 2014).

The current economic downturn is affecting many European Member States (MSs). Ten Member States experienced negative rates of change during 2008-2011. Three countries (Denmark, Spain and Ireland) experienced an even longer period of downturn which lasted for 4 consecutive years. In contrast, seven Member States recorded an increase in construction output in 2010.

The production value of the construction sector is a picture of the dominating activities occurring in Europe leading to employment and trade. In 2011, the production value for the construction sector in EU-28 was 1,555,007 Million Euro.

Construction materials

Aggregates

Aggregates are one of the most important used materials in road construction since they constitute the bulk volume of the road pavement structure. They are employed in unbound and bound mixtures in different road layers and, according to the source material, can be classified as:

- natural aggregates, produced from mineral sources; sand and gravel are natural aggregates resulting from rock erosion; crushed rock is extracted from quarries;
- recycled aggregates, produced from processing material previously used in construction;
- secondary aggregates, which include manufactured aggregates, natural secondary aggregates and extraction by-products for construction and civil engineering (EC JRC, 2009; Böhmer et al., 2008; EC JRC, 2014; WRAP, 2014) (see section 2.3.1).

In EU-28, approximately 2.8 billion tonnes of aggregates were produced in 2010, representing a value of 20 billion Euros (UEPG, 2012). Total aggregate production is dominated by sand and gravel (42%) and crushed rock (48%). Recycled and manufactured aggregates only account for 6% and 2% of total production respectively (UEPG, 2012), however in some MSs, recycled aggregates account up to 15%. However, it is expected that the contribution of unconventional aggregates to the sustainable supply mix (SSM) of aggregates is likely to increase by a large extent in the future.

Aggregates are primarily produced by small and medium sized companies operating in about 22,400 sites across Europe. The number of employees is approximately 250,000 people including contractors.

Around 20% (some 500-600Mt) of aggregate production is used in roads, runways, railways and waterways in the EU (UEPG, 2012). Of this quantity, at least half is considered to be used in road construction and maintenance in the EU. The type of aggregates most commonly used in roads are of the crushed rock type. For a general idea of how much aggregate is used for road construction on a per km basis, the following figures can be considered:

- 20,000 t/km for a two-lane road (EC, 2010);
- 10,000 m^3/km of two lane road (OECD, 1997) which equals approximately to 20,000 t/km;
- 30,000 t/km for a motorway (EC JRC, 2009).

Asphalt material used in pavement

According to stakeholder feedback to a questionnaire distributed in 2013, in Europe the main pavement layer type is the flexible (asphalt) one. The UK Road Administration has reported that in the UK, 96% of pavements are flexible. The Danish Road Directorate has reported that that 100% of all pavements are flexible and in the Netherlands 97% of all pavements are flexible. Stakeholders feedback received after the 1st AHWG confirmed that more than 95% of main pavement layer type in Europe are flexible and that this data is referred to all type of courses involving binders, not only to surface course. According to EUPAVE, the percentage of rigid pavements for motorways can go from 0 to 50 % in different MSs.

There are three generic types of asphalt mixture that can be used: hot mix asphalt (HMA), warm mix asphalt (WMA) and cold mix asphalt (CMA). The dominant binder type is HMA, accounting for over 300 Mt each year in the EU since at least 2006. Annual production of WMA and CMA are around 7 Mt and 3 Mt respectively, accounting for only 2% of total asphalt production combined (EAPA, 2012). However, it is foreseeable that WMA will become much more significant as experience increases with this lower energy consumption and lower emission technique.

Concrete

European roads are roughly 90% flexible (asphalt) and 10% rigid (concrete) according to 'The Asphalt Paving Industry (NAPA and EAPA, 2011). The stakeholders also confirm this fact in the questionnaires that only approx. 5% of the roads are rigid and 95% are flexible roads. It is uncertain to whether this information refers simply to surface courses or also to underlying binder and bound base courses. Consequently it is difficult to estimate the total quantities of cement concrete used in road construction in the EU.

Recycled materials and by-products[4]

In 2011, the EC issued two Communications on ‘A resource efficient Europe’ and ‘Roadmap to a Resource Efficient Europe’. The overall idea is to reconsider the whole life cycle of resource use, so as to make the European Union a ‘circular economy’ based on recycling and the use of waste as a resource (EC COM(2011) 21, *A resource- efficient Europe – Flagship initiative under the Europe 2020 Strategy*; COM(2011) 571, *Roadmap to a Resource Efficient Europe*). There is a strong connection with the Directive 2008/98/EC, the so-called Waste Framework Directive (WFD), which revised the legal framework for waste based on the entire life cycle, from generation to disposal, with an emphasis on waste prevention, re-use, recycling and recovery (EU, 2008). In this report we refer to re-used/recycled/recovered materials and by-products as defined in the WFD.

Member States in Europe have developed individual guidelines and regulation regarding the use of waste products in Europe (EC JRC, 2009), diversifying the overall picture at the European level. Examples are reported in section 2.3.1. For example, Construction and Demolition waste (C&DW) has been identified by the EC as a priority stream because of the large amounts that are generated and the high potential for re-use and recycling of these materials. For this reason, the WFD requires MS to take any necessary measures to achieve a minimum target of 70% (by weight) of C&DW by 2020 for preparation for re-use, recycling and other material recovery, including backfilling operations using non-hazardous C&DW to substitute other materials. The above target excludes naturally occurring material, defined under code 17 05 04 as "soil and stones" in the European Waste Catalogue. According to EC JRC 2009, the mineral fraction of C&DW is seen as a potential material for producing recycled aggregates. Data from Eurostat (Eurostat, 2012b) indicates that

4 as defined by art. 5 of the Waste Framework Directive (WFD) 2008/98/EC: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2008:312:0003:0030:en:PDF

the total mineral C&DW in the EU-27 is 341 Mt per year. However, according to BIOIS (BIOIS EC, 2011) the total amount of C&DW generated in EU-27 is approx. 531 Mt per year.

Other re-used/recycled/recovered materials and by-products, such as iron and steel slags, coal combustion ashes, municipal solid waste incineration (MSWI) bottom ash, reclaimed rubber from tyres, etc., could be employed in road construction, following the requirements of EU and national legislation and standards, allowing natural resources savings, although they don't have a specific recycling target fixed in the WFD.

Market segmentation

Road types

The total length of the EU road network is about 5.3 million km, of which around 1.3% are motorways. The category "other roads" accounts for the largest share of road network length. The distribution of roads types in the single Member States varies significantly. A comparison between countries is complicated because different countries have different definitions for each road type. With regards to roads defined as motorways, the proportion compared to the total road network span varies from approx. 0.1% to more than 5% (ERF, 2013).

The distribution of roads by classification with individual Member States is also shown in Figure 3 The road classifications from left to right are in descending order of width or traffic volume in general as per each Member State's definition. Figure 3 shows that no "other roads" were present in Romania, Luxembourg and Denmark. However, this is simply due to the definition system in these countries. In general, it is clear that the smaller "other roads" are by far the category that accounts for the majority of road length in each country. As suggested by a stakeholder, the evolution of roads length per km^2 has been also shown (unfortunately only for motorways) in order to highlight the different relevance of road types.

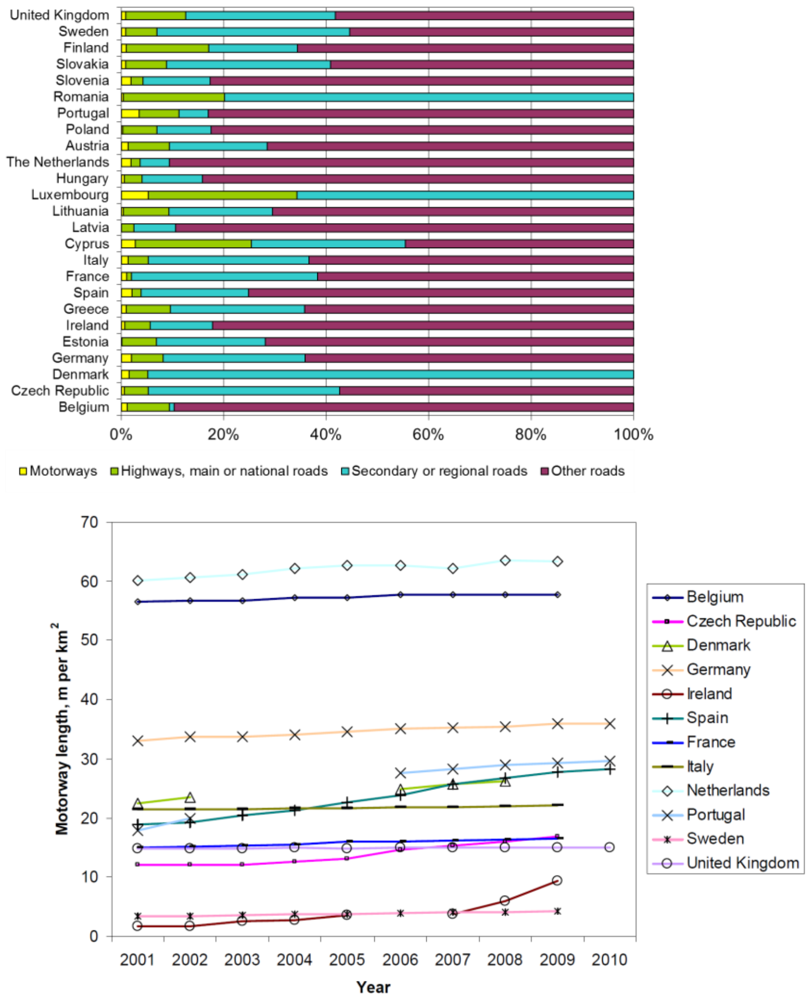


Figure 3: Distribution of roads types within the Member States of Europe (based on data ERF, 2013) and ten years evolution of motorway length per km^2 for EC MSs (EC, JRC, 2012a).

Maintenance

The need for maintenance varies significantly depending on numerous aspects, *e.g.*, traffic volume/density, heat stress, type of road (rigid, composite or flexible), underground conditions, proximity to the coast, intense precipitation, share of heavy vehicles in traffic flow, frost depth, freeze-thaw cycles, *etc.* (EC JRC, 2012b).

The cost of EU infrastructure development to match transport demand has been estimated at over €1.5 trillion for 2010-2030[5]. The completion of the TEN-T network requires about €550 billion by 2020[6]. Data from the European Road Statistics (ERF, 2013) reveals that the relative expenditure on maintenance in 2009 can vary significantly between different countries. The total expenditure in road maintenance for all Member States is estimated by the International Transport Federation, and summarised in the European Road Statistics (ERF, 2013), as 26 billion euro in 2009.

1.3 The environmental impacts of road construction and maintenance

A common conclusion from the LCA literature review done in this study (see the Preliminary Report) is that almost all roads are unique and have their own specific conditions. According to Carlson (2011) and Santero *et al.* (2011a,b), it is impossible to perform straightforward comparisons of the results in reviewed LCA studies due to the differences in approach, scope, functional units, analysis periods, system boundaries, regional differences, input data (Life Cycle Inventories, or LCIs) (see preliminary report and Annex III literature review). This means that a flexible method is needed that can be adjusted to suit the road that you want to study.

A large range of impacts are possible for all the components of the road life cycle. Santero and Horvath (2009) stated that GHG emissions could range from negligibly small values to 60,000 t of CO_2e per lane-kilometre over a service life of 50 years. The main environmental impacts arise from daily traffic (fuel consumption by cars and heavy trucks) during the use phase of a road.

Rolling resistance associated to the pavement structure and roughness generally has the highest-impact potential, because it is directly related to the vehicle fuel consumption. According to Wang et al. (2012a), a 10% reduction in rolling resistance could lead to 1-2% of improvement in fuel economy.

Congestion can be due to factors outside of the scope of public works (like rush hour traffic, accidents, breakdowns and adverse weather conditions) or due to factors directly related to them, such as lane/road closures necessary for road construction and/or maintenance. It can greatly influence vehicle fuel consumption due to queues and associated slowdown, both in the construction and in the maintenance phase. The environmental impacts associated with congestion are dependent upon the project and site characteristics. For low traffic roads, the impacts of congestion are likely to be negligible. Conversely, on motorways and highways, the extra fuel consumption and related air emissions can easily become a prominent component of the road life cycle. In order to reduce the environmental impacts of road maintenance works, effective traffic management (lane closure, traffic diversion) and phasing of the roadwork into off-peak hours (night shifts) have to be planned and will be considered as a GPP criterion.

An important factor is the influence of **traffic flow** on the relative importance of the identified hot spots (Figure 4):

- In high traffic roads (*i.e.*, example motorways, highways, and main national roads), rolling resistance and congestion have the highest impacts on energy consumption and emissions. Materials production and transportation is the third most important aspect to be taken into consideration.
- In low traffic roads (*i.e.*, secondary and other roads): higher impacts on energy consumption and emissions come from materials production and transportation rather than from rolling resistance and congestion. The relative importance of materials production and transportation increases with the decrease of the traffic flow.

5 http://ec.europa.eu/transport/strategies/facts-and-figures/investing-in-network/index_en.htm

6 EC calculations based on TEN-tec Information System and the Impact Assessment accompanying the White Paper, SEC(2011) 358

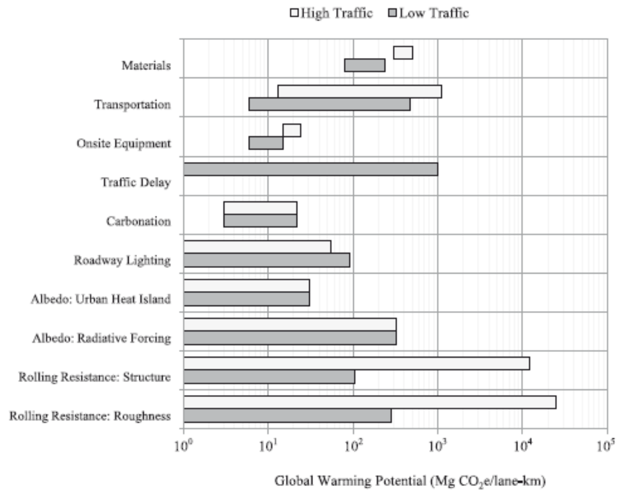


Figure 4: Comparison of GWP ranges for low and high-traffic pavements (In this case, the low traffic scenario is modelled as 425 AADT, 8% heavy) **(Santero *et al.,* 2011a)**.

Internationally, roads with traffic flows of less than 2000 vehicles per day are denoted as low volume roads (AASHTO, 1993).

Road alignment is also a prevailing parameter on the fuel consumed by traffic during the use phase. Alignments are decided upon in the preliminary phase of the procurement route, specifically during road planning and environmental impact assessment. Therefore, road alignment will not be considered as a possible GPP criterion. Nonetheless, it is recommended that the public authorities are aware of the importance of this parameter and include this knowledge when choosing the alignment of the road construction.

The road life cycle stage with the second largest environmental impacts is indicated to be the construction phase, in which the hot spots are related to **materials production** and **transportation**. The main environmental impacts are consumption of non-renewable resources, global warming, acidification, photochemical ozone formation and eutrophication in the majority of the investigated studies. In particular:

- In concrete pavements, **cement** production and **concrete** mix (including **aggregates**) are responsible for the main impacts.
- In asphalt pavements, **bitumen** production and **asphalt** mix (including **aggregates**) are responsible for the main impacts.
- **Materials transportation** could account up to 50% of the energy consumption and emissions, depending on the local conditions. A stakeholder stressed that materials transportation can in some cases overwhelm the materials production.

In complex orography condition, the impacts related to **earthworks** and **ground works**, including soil stabilization, can accounted for the main part of the total emissions and up to 30% of the project cost (Barandica *et al.*, 2013). Rock blasting is also included in this area; as a stakeholder underlined, this could cause relevant environmental impacts.

In the literature review no general rules have been found on the choice of the materials, for example asphalt or concrete, for the pavements construction. The choice of materials depends on the uniqueness of the local conditions, as geotechnical and hydrogeological conditions, common practices of the road administrations, climate conditions, availability of natural resources and **recycled resources and by-products**, **transportation distances**, and prices, with particular regard to the optimisation of maintenance and rehabilitation strategies to guarantee desirable performances (for example, rolling resistance due to pavement-vehicle interaction, durability and noise reduction). The final choice of materials will be based on the project specific characteristics and on the needs and indications of the public authority.

With reference to the results of the market analysis and the stakeholder consultation, it can be highlighted that nowadays **maintenance and rehabilitation** is gaining an increased relevance due to decreases in new road construction. Maintenance has to be evaluated not as a simple repetition of restoration and repairing activities, but on the contrary as a complex network of design strategies including evaluation on rolling resistance, congestion and durability of road surface materials. This phase is dominated by material production and congestion, similar to the construction phase. Several studies indicate that there is a clear connection between durability and sustainability aspects. Thus when durable materials are used, the need for maintenance is reduced.

Some other impacts that are not generally included in LCA studies of roads but which are of particular importance are: **environmental noise emissions** and **stormwater drainage**. The importance of these areas is reflected in the Environmental Noise Directive (2002/49/EC), the Water Framework Directive (2000/60/EC) and the EU Floods Directive (2007/60/EC).

Roads present large impermeable surface areas and are designed to rapidly convey stormwater away from the road surface by gravity for obvious safety reasons. Drainage systems have traditionally been designed to simply prevent the target area from flooding, but many systems simply pass the risk of flooding to downstream areas. According to the European Environment Agency, over 175 major floods were recorded in EU member states between 1998 and 2009, with insured economic losses of around **€52 billion** (EEA, 2010).

There is a huge opportunity for road drainage systems to provide much needed **flood capacity** in flood risk areas. Today two broad types of engineered drainage systems exist which can be distinguished as "**hard engineering**" (more concrete based) or "**soft engineering**" (less concrete based). In terms of flood management, both can be tailored to significantly reduce the risk of flooding downstream.

A number of pollutants are transferred from roads to watercourses, such as sediments, litter, worn tyre particles, oils and particulates from exhaust gases that are captured from the air by falling rain. The key to treating stormwater and removing pollutants from roads is to remove floating material (litter and oils) and solid particles (sediment). These treatments can be achieved by "hard" or "soft" engineering approaches but the success of any drainage system will depend on appropriate maintenance.

With regards to environmental noise, road traffic is perhaps the single most dominant source across most of the EU. There are two possible approaches to reduce noise from road traffic: a) to specify low-noise road surfaces; b) to install noise barriers.

Both approaches have their advantages and disadvantages. For example, there are concerns about potentially higher maintenance requirements of certain low-noise road surfaces and noise barriers may not be practical in many urban locations. Furthermore noise barriers could result in significant environmental impacts depending on what materials are used. Nonetheless, significant improvements in environmental noise from road traffic can be achieved via this GPP product group and so potential criteria are worth considering.

1.4 GPP criteria for Road design, construction and maintenance

The key environmental areas to be addressed, as well as the key life cycle environmental impacts, are summarised below, as well as the overall GPP approach and focus for road construction and maintenance, based on the background evidence analysed during the criteria development process.

Key Environmental Areas in Road Construction life cycle and Key Environmental Impacts

Key environmental areas:

- Rolling resistance due to the pavement-vehicle interaction, and related fuel consumption, and associated greenhouse gas emissions, during the use phase of a road;
- Depletion of natural resources, embodied energy and emissions associated with the manufacturing and transportation of road construction materials;
- Excavated materials and soil, including topsoil, generated during site preparation, earthworks and

groundwork. Construction and demolition of the road;

- Noise emissions from road construction, use and maintenance;
- Durability of the pavement surface courses. Optimisation of maintenance strategy to guarantee desirable performance for rolling resistance, durability and noise reduction;
- Congestion due to construction and maintenance works;
- Water pollution during road construction and during the use phase. Contribution of road surfaces to flooding. Habitat fragmentation and risks to flora and fauna during the road use phase.

Key life cycle environmental impacts and parameters for resource use:

- The following key environmental impact categories along the product life cycle are considered the most important ones: global warming potential, photochemical ozone formation, abiotic resource depletion, acidification, eutrophication, human toxicity, eco-toxicity, land use, exploitation of renewable and non-renewable primary energy resources, use of secondary and re-used materials and waste material flows.

Proposed EU GPP Road Design, Construction and Maintenance approach

- Design and construction to achieve low rolling resistance (within technically acceptable safety parameters) and low associated fuel consumption and emissions in motorways and highways by means of optimizing the macrotexture (measured as Mean Profile Depth MPD) and monitoring it during the road use phase;
- Design and specification to reduce the embodied impacts and resource use associated with construction materials;
- Design, specification and site management to maximize the on-site re-use of excavated materials and soils (including topsoil), maximize the re-use/recycling of construction and demolition waste (C&DW) and of waste from other industrial processes and to use construction materials with a high recycled or re-used content including by-products;
- Specification of approaches to lower noise emissions (including nature-based solutions[7]) during construction, use and maintenance phase;
- Increasing material durability and reducing maintenance needs;
- Maintenance and rehabilitation strategies including a monitoring plan and a maintenance plan;
- A Traffic Congestion Mitigation Plan including solutions such as alternative routes, tidal flow lanes and hard shoulders evaluated by means of an LCC analysis;
- Introducing water pollution control components and stormwater retention capacity components, including soft engineered solutions (e.g. nature-based solutions) in the drainage system, including potential for habitat creation notably to reduce runoff into storm sewers and the overall amount of water entering local storm sewers or surface waters thereby significantly reducing flooding-related damages.

For better readability of this document, a list of the proposed GPP criteria for Road design, construction and maintenance with a brief description of the contents is summarised in Table 1. Not all of the criteria will be relevant for all projects and forms of contracts. Unless otherwise noted in brackets, the criteria areas are relevant to both Core and Comprehensive criteria.

7 Nature-based solutions are locally adapted, resource efficient and systemic interventions that are inspired or supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience.

Table 1. Brief description of the contents of the proposed GPP criteria for Road Design, Construction and Maintenance.

Title of the criterion	Procurement phase	Description
Criteria related to the ability of the tenderer		
Competencies of the project manager and the design team	Selection of the design team and contractors	*Experience and expertise in:* - *Evaluation of pavement-vehicle interaction;* - *Specification of resource efficient construction materials;* - *Traffic noise mitigation;* - *Congestion mitigation;* - *Pavement durability;* - *Stormwater pollution control and retention capacity in drainage systems.*
Competencies of the lead construction contractor, specialist contractors and/or property developers	Selection of the design team and contractors	*Experience and expertise in:* - *Maintenance and rehabilitation strategies plan;* - *Procurement of resource efficient construction materials;* - *Implementation of Demolition Waste Management Plan and Excavated Materials and Soil Management Plan.*
Pavement-vehicle interaction		
Pavement-vehicle interaction Performance requirements on rolling resistance	Detailed design + construction	- *Performance requirements for lowering the macrotexture of the road surface in compliance with the safety conditions in order to lower the fuel consumption during the use phase;* - *Monitoring performance parameters.*
Resources efficient construction		
Life cycle performance Performance requirements of the main road elements	Detailed design + construction + maintenance and operation	*LCA performance [carbon footprint (Core) or LCA (Comprehensive) options] of the main road elements:* - *Sub-ground including earthworks and ground works;* - *Sub-base and road-base;* - *Base, binder and surface course or concrete slabs;* - *Ancillary elements (optional).*
Recycled content	Detailed design + construction + maintenance and operation	*15% (Core) and 30% (Comprehensive) including re-used/recycled materials and by-products such as RAP, SCMs, recycled and secondary aggregates in the main road elements.*
Materials transportation CO_2e emissions from transportation of aggregates	Detailed design + construction + maintenance and operation	*This criterion could be applied if the criterion on carbon footprint or LCA is not applied.* - *Reduction of CO2e emissions per each ton of transported material.*
Asphalt		
Tar-containing asphalt	Maintenance and operation	*Identifying the best available techniques to treat and/or eventually re-use the tar-containing asphalt.*
Low temperature asphalt	Detailed design + construction + maintenance and operation	*Maximum laying temperature of bituminous mixtures of 140° (Core) and 120° (Comprehensive). Higher temperatures allowed for special bituminous mixtures, in any case lower than 155°.*
Soil and Waste Management Plan		
Excavated Materials and Soil Management Plan	Detailed design + construction	- *Specification of quantity of soils to be moved off-site and overall site soil balance. Estimates of materials diverted from landfill, % of materials re-used and/or recycled on-site, % of materials re-used and/or recycled off-site;* - *Management of top-soil.*
Demolition Waste Management Plan	Maintenance and operation + End of Life	- *70% (Core) and 90% (Comprehensive) by weight in the main road elements;* - *Bill of quantities and methods for recycling and re-use;* - *On-site monitoring and accounting.*
Water and habitat conservation		
Water pollution control components in drainage system	Detailed design + construction	*Appropriate design of the drainage system and inspections* *Incorporation of soft engineered components (i.e., SuDS).*
Stormwater retention capacity	Detailed design + construction	*Appropriate design of the drainage system and inspections* *Incorporation of soft engineered components (i.e., SuDS).*
Environmental Integration and Restoration Plan	Detailed design + construction + maintenance and operation	*A site map, a description of the procedure used to select plant species, planting bed requirements and planned measures to avoid soil erosion.*
Wildlife passages across the road	Detailed design + construction	*Drainage infrastructure that aids the safe passage of small animals, amphibious species an/or aquatic species*
Noise		

Noise emission during construction and maintenance	Detailed design + construction + maintenance and operation	*Measurement of noise emission and monitoring in the construction and maintenance phases.*
Low-noise surface pavements	Detailed design + construction	*Measurement of noise emission via CPX methods prior to opening and monitoring at regular periods and conformity of production testing*
Other environmental criteria		
Lighting	Detailed design	*Reference to EU GPP criteria for Street lighting*
Road markings	Detailed design	*Reference to the EU GPP criteria for paints, varnishes and road markings (under development)*
Congestion		
Traffic congestion mitigation plan	Detailed design + construction + maintenance and operation	- *Timeline including expected construction and/or maintenance activities;* - *Alternative routes for diverted traffic and other solutions such as tidal flow lanes, hard shoulders, information to users IT systems.*
Maintenance and rehabilitation strategies		
Durability	Detailed design+ construction maintenance and operation	*Setting a minimum nominal service lifetime of the road pavement, not lower than:* - *15 years (Core) and 20 (Comprehensive) for the binder course;* - *20 years (Core) and 40 (Comprehensive) for the base course for flexible/semi-rigid pavements and for the concrete slab for rigid pavements;* - *40 years (Core) and 60 years (Comprehensive) for the sub-base.*
Maintenance and rehabilitation strategy plan	Detailed design + use + maintenance	- *Providing a monitoring plan including the performance parameters, frequency of monitoring, etc.;* - *Providing a maintenance and rehabilitation (M&R) strategic plan with the strategies for maintenance and rehabilitation including routine, preventive and rehabilitation actions.*

1.5 Applicability of the GPP criteria for Road Design, Construction and Maintenance

Designing and procuring road construction, maintenance or rehabilitation activities with a reduced environmental impact is a complex process. In light of this complexity, a guidance document has been developed to provide procurers with orientation on how to effectively integrate the GPP criteria for Road design, construction and maintenance into the procurement process (see the *Procurement practice guidance document*, provided as a separate document).

The process of constructing a new road or carrying out a maintenance activity consists of a distinct sequence of procurement activities with related contracts. This sequence of procurement can have a significant influence on the outcome. This is because each type of contract brings with it distinct interactions between the procurer, the road design team and the contractors.

Depending on the procurement route adopted, these contracts may be awarded to the same contractor or are let separately. Some contracts may be integrated in a Design and Build (DB) or a Design, Build and Operate (DBO) arrangement, with the detailed design process, the main construction contract, the maintenance and operation contract all potentially co-ordinated by one contractor.

It is therefore important to identify the main points in the sequence of procurement activities where GPP criteria should be integrated. To this end these criteria are accompanied by a draft guidance document which provides general advice on how and when GPP criteria can be integrated into this process.

Depending on the ambition level of the project, time constraints and the experience of the contracting authority, not all of the GPP criteria included in this criteria set will be relevant. Moreover, depending on the preferred procurement sequence criteria may be best addressed at specific stages. Some activities may be let as separate contracts requiring their own criteria.

The strategic objectives and targets of the project should be determined at the outset of the project with reference to the GPP criteria set. The optimum stages for integration of GPP criteria should be evaluated during discussions to determine the procurement route. In all cases it is recommended that GPP criteria are integrated into both internal planning and the procurement sequence at as early a stage as possible in order to secure the desired outcomes and achieve the best value for money.

2 Criteria proposal

2.1 Selection criteria

2.1.1 Selection criteria on the competency of the project manager and the design team

The selection criteria have been specified to encompass the range of competencies that would be required to deliver an environmentally improved road construction and maintenance. These reflect the need for experience in specific technical areas as well as in the successful management of technical innovation in this field.

The first proposed criterion concerns the project manager and the design team, who have a critical role to play in selecting, modelling, specifying and integrating solutions to meet environmental criteria. Working alongside the design team, the role of the project manager is also identified as being significant in managing technical innovation. Given the increasing prevalence of civil works environmental assessment schemes, experience and expertise in applying them to projects is also judged to be of value in managing a design teams' response to a range of environmental criteria.

The second criterion is proposed as focussing on the main contractor and possible specialist contractors. The competency of property developers and investors that lead bids could also be addressed.

Selection criteria on the competencies of the project manager and design team

Core criteria	**Comprehensive criteria**
SELECTION CRITERIA	
These criteria may form part of a pre-selection procedure where a design team are procured by the contracting authority. The number and size of executed projects to prove the experience should be proportionate to the tendered project.	
A1. Competencies of the project manager and design team *These criteria may form part of a pre-selection procedure for the main contractor or where the services of a design team are procured by the contracting authority.* The project manager, planners, engineers, architects, consultant and/*or* design team consortium shall have relevant competencies and experience in each of the following areas for which they would be responsible under the contract *(select as relevant to the specific contract):* - The project management of road construction and maintenance contracts that have delivered improved environmental performance; - Assessment of road environmental performance using multi-criteria certification schemes and carbon footprint tools in compliance with ISO 14067 or equivalent; - The specification, procurement and use of low environmental impact construction materials; - The use of construction materials with high recycled and re-used content and by-products in road construction and maintenance; - Traffic congestion mitigation plans and LCC analysis to identify the cost-optimal solution; - Real life road traffic noise mitigation solutions by means of low-noise pavements and noise barriers; - Increasing the durability of pavement courses,	**A1. Competencies of the project manager and design team** *These criteria may form part of a pre-selection procedure for the main contractor or where the services of a design team are procured by the contracting authority.* The project manager, engineers, architects, consultant and/*or* design team consortium shall have relevant competencies and experience in each of the following areas for which they would be responsible under the contract *(select as relevant to the specific contract):* - The project management of road construction and maintenance contracts with improved environmental performance; - Evaluation of unevenness and macro-texture effects on rolling resistance and, consequently, on fuel consumption and relationship with skid resistance. Evaluation of macrotexture (measured as MPD) and durability related to construction materials. Use of MIRAVEC tool or, where existing, other assessment tools to evaluate fuel consumption; - The use of holistic assessment tools in the design and specification of environmentally improved roads including LCC and LCA. Comparative studies in compliance with ISO 14040 and ISO 14044; - The specification, procurement and use of low environmental impact construction materials; - The use of construction materials with high recycled and re-used content and by-products in road

bearing capacity and fatigue resistance; - Development and execution of monitoring and maintenance plans in real life cases; - Design and installation of stormwater pollution control components and stormwater retention capacity, ideally including soft engineered components, in the drainage systems. Project experience and Continuous Professional Development (CPD) of relevance to these areas shall be highlighted. *The contracting authority may increase the number of years for the collection of the technical evidence and may require proof of a minimum number of contracts according to the nature of the project.* **Verification**: Evidence in the form of information and references related to relevant contracts in the previous 5 years in which the above elements have been carried out. This shall be supported by CVs of personnel who will work on the project.	construction and maintenance; - Traffic congestion mitigation plans and LCC analysis to identify the cost-optimal solution; - Real life road traffic noise mitigation solutions by means of low-noise pavements and noise barriers; - Increasing the durability of pavement courses, bearing capacity and fatigue resistance. Experience in long lasting pavements and perpetual pavements; - Development and execution of monitoring and maintenance plans in real life cases; - Design and installation of stormwater pollution control components and stormwater retention capacity, ideally including soft engineered components, in the drainage systems. Project experience and Continuous Professional Development (CPD) of relevance to these areas shall be highlighted. *The contracting authority may increase the number of years for the collection of the technical evidence and may require proof of a minimum number of contracts according to the nature of the road project.* **Verification**: Evidence in the form of information and references related to relevant contracts in the previous 5 years in which the above elements have been carried out. This shall be supported by CVs of personnel who will work on the project.

2.1.2 Selection criteria on the competency of the construction/ maintenance/ rehabilitation contractors

Selection criteria on the competencies of the main construction contractor

Core criteria	**Comprehensive criteria**
SELECTION CRITERIA	
A2. Competencies of the main construction contractor *These criteria may form part of a pre-selection procedure for the main contractor.* The main construction contractor shall have relevant competencies and experience in the completion of road construction and maintenance contracts that have been shown to have delivered improved environmental performance. In the case of Design and Build (DB) *or* Design, Build and Operate (DBO) contracts, criterion A2 will also be relevant to the design team employed. Relevant areas of experience shall include (as appropriate to the project and the selected GPP criteria): - The commissioning of monitoring and routine maintenance activities on macro-texture (MPD); - Evaluation of durability related to construction	**A2. Competencies of the main construction contractor** *These criteria may form part of a pre-selection procedure for the main contractor.* The main construction contractor shall have relevant competencies and experience in the completion of road construction and maintenance contracts that have been shown to have delivered improved environmental performance. In the case of Design and Build (DB) *or* Design, Build and Operate (DBO) contracts, criterion A2 will also be relevant to the design team employed. Relevant areas of experience shall include (as appropriate to the project and the selected GPP criteria): - The commissioning of monitoring and routine maintenance activities on macro-texture (MPD) and evaluation of the fuel consumption due to changes

materials; - The commissioning of a road congestion mitigation plan and management of congestion during construction and maintenance, including solutions such as alternative routes, tidal flow lane, hard shoulder, ITS devices and their evaluation by means of LCC analysis; - The purchasing and use of low environmental impact construction materials and verification of their performance. Supply chain management to ensure compliance with any relevant road assessment and certification systems, for example CEEQUAL or Greenroads, *etc.*; - The purchasing and use of construction materials with high recycled and re-used content and by-products in road construction and maintenance; - The successful implementation of demolition waste and excavation materials and soil management plans in order to minimise waste production. Selection and knowledge of on-site and off-site treatment options; - Experience with low temperature asphalt with particular regards to best techniques related to health and safety of workers; - Construction of low-noise pavements; - Long lasting pavements and increase of durability of the surface layers of the pavement; - Construction and commissioning of water pollution control components and stormwater retention capacity, including soft engineered components. Project experience and Continuous Professional Development (CPD) of relevance to these areas shall be highlighted. *The contracting authority may increase the number of years for the collection of the technical evidence and may require a minimum number of contracts according to the nature of the project.* **Verification:** Evidence in the form of information and references related to relevant contracts in the last 5 years in which the above elements have been carried out. This shall also be supported by CVs for personnel who will work on the project.	in MPD, unevenness and surface defects; - Evaluation of durability related to construction materials. Use of MIRAVEC tool or, where existing, other assessment tools to evaluate fuel consumption; - The commissioning of a road congestion mitigation plan and management of congestion during construction and maintenance, including solutions such as alternative routes, tidal flow lane, hard shoulder, ITS devices and their evaluation by means of LCC analysis; - The purchasing and use of low environmental impact construction materials and verification of their performance. Supply chain management to ensure compliance with any relevant road assessment and certification systems, for example CEEQUAL or Greenroads *etc.*. Experience with LCA and LCC tools; - The purchasing and use of construction materials with high recycled and re-used content and by-products in road construction and maintenance; - The successful implementation of demolition waste and excavation materials and soil management plans in order to minimise waste production. Selection and knowledge of on-site and off-site treatment options; - Experience with low temperature asphalt with particular regards to best techniques related to health and safety of workers; - Construction and monitoring of low-noise pavements, analysis of the durability of noise reduction performance; - Long lasting pavements and increase of durability of the surface layers of the pavement; - Construction and commissioning of water pollution control components and stormwater retention capacity, including soft engineered components. Project experience and Continuous Professional Development (CPD) of relevance to these areas shall be highlighted. *The contracting authority may increase the number of years for the collection of the technical evidence and may require a minimum number of contracts according to the nature of the project.* **Verification:** Evidence in the form of information and references related to previous contracts in the last 5 years in which the above elements have been carried out. This shall be supported by evidence and data from: - Third party auditing (for example from the demolition waste audit); - LCA/LCC analysis of the main road element and/or; - Data collection from monitoring of, for example, the production and management of C&DW and excavated materials and soil, the performance parameters for road routine and preventive

	maintenance and rehabilitation, *etc.*. This shall also be supported by CVs for personnel who will work on the project

Supporting notes:

- The evaluation of consultants, design teams and contractors requires an experienced evaluation panel. It may be appropriate to bring in external expertise, which may include appointment of a project manager, and the setting up of a panel with the knowledge and experience to judge the experience of competing contractors. The lists included in selection criterion 1 and 2 are indicative and should be adapted to the project and the procurement stage.
- In the reform of the Public Procurement Directives[8,9] (published in the Official Journal 28th March 2014 and requiring transposition by Member States within 24 months), it is explicitly stated (Art. 66 of Directive 2014/24/EU) that the organisation, qualification and experience of staff assigned to performing the contract (where the quality of the staff assigned can have a significant impact on the level of performance of the contract) can be a criterion for awarding a contract. For complex contracts such as road contracts it can usually be expected that the quality of the project managers, design team, specialist consultants and contractors can have a significant impact on the performance of the project. Please note that the educational and professional qualifications of the service provider or contractor or those of the undertaking's managerial staff may only be evaluated *once* in a tender procedure, either at selection stage or as an award criterion (Annex XII, Part 2 f of Directive 2014/24/EU).

8 Directive 2014/24/EU on public procurement and repealing Directive 2004/18/EC.

9 Directive 2014/25/EU on procurement by entities operating in the water, energy, transport and postal services sectors and repealing Directive 2004/17/EC.

2.2 Pavement-vehicle interaction criteria

2.2.1 Background technical aspects, discussion and rationale for rolling resistance

The literature review shows that rolling resistance associated with pavement structure and roughness plays an important role in the vehicle fuel consumption.

Milachowski C. *et al.* (2011) have analysed 1 km of asphalt and concrete motorway over a service life of 30 years and they have considered different scenarios of decreases in fuel consumption due to road surface properties. They concluded that fuel consumption could be reduced by 5-20% when the road surface is optimized, *i.e.*, with reduced unevenness (macro-texture) and increased stiffness.

Häkkinen and Mäkele (1996) have evaluated that a reduction of vehicle fuel consumption of around 0.1-0.5% due to the concrete pavement properties would bring energy consumption savings of the same order of magnitude as those used for materials production and construction of a concrete pavement and savings in CO_2 emissions of 50% compared to those from materials production and construction of a concrete pavement.

Wang *et al.* (2012a) analysed energy consumption and GHGs emissions from pavement rehabilitation strategies. Furthermore, case studies are described in the study to evaluate the effect of rolling resistance on the life cycle performance of the selected pavement. Concrete and asphalt pavements are included in the study where the material production, construction, use (including rolling resistance) and maintenance phases of the road life cycle are addressed.

It was concluded that traffic during the use phase dominates the life cycle impacts of a road construction with expected high traffic volume. The authors referred to studies indicating that a 10% reduction in the rolling resistance can lead to 1-2% improvement in fuel economy (Evans *et al.*, 2009, Tiax *et al.*, 2003 and Transportation Research Board, 2006). Furthermore, the study identifies two main benefits of smooth pavements: reduced fuel consumption and slower rate of pavement deterioration. The latter also causes reduced materials consumption due to less need for maintenance and repair of the road surfaces.

The study also concluded that there is a great potential for reduction of environmental impacts exists by reducing the roughness of the road surface to reduce rolling resistance on high-traffic roads [providing examples with 34,000, 86,000 and 11,200 AADT (Annual Average Daily Traffic)]. For roads with less traffic volume the construction quality and the materials production become more important, due to the fact that the share of the potential environmental impacts from the use phase naturally becomes lower and because the total energy use from the traffic is lower due to reduced number of vehicles. No general rule can be given concerning the size of the potential environmental impacts caused in the use phase compared to the material and construction phases. Nevertheless an example is provided in the study where a smaller road with 3,200 annual average daily traffic is assessed. In this specific scenario, materials production and construction phase were calculated to be three times higher than the impacts during the use phase.

In Wang *et al.* (2012b), total energy use and GHG emissions from materials production, construction, use and maintenance are evaluated. The paper also evaluated the effects of changing road unevenness and macro-texture on rolling resistance. Scenarios with low and high traffic volume are evaluated and the main results are listed below:

- It is concluded that for roads with high traffic volume, when the roughness and **macro-textures** were improved, the reduction in energy consumption and GHG emissions can be significantly larger than the emissions from materials production and construction. The reduced roughness contributed to the largest savings in energy consumption and GHG emissions;
- The authors include another parameter, i.e. the increase of **unevenness**, and consequently of the rolling resistance, during the life cycle of the road. The results of the NCHRP report (Chatti and Zaabar, 2012) show a relationship between roughness and surface texture, and fuel consumption as follows: an increase in International Roughness Index (IRI) of 1 m/km will increase the fuel consumption of passenger cars by about 2%, independent of velocity. For heavy trucks, this increase is about 1% at normal highway speed (96 km/h) and about 2% at low speed (56 km/h). The third pavement factor to influence rolling resistance is **deflection**, but the authors excluded this factor from the study because relations between pavement deflection and rolling resistance are still being researched;

- For roads with low traffic volume the share of impacts from the use phase is reduced overall compared to the impacts from the material production and construction phases.

Loijos *et al.* (2013) have analysed the Global Warming Potential (GWP) of 1 km of concrete pavement for 12 different structures of the US roadway network (from interstate to local roads in rural and urban areas) over a service life of 40 years. In this study, vehicle fuel consumption has been allocated to the pavement based on roughness increase over the life cycle. Thus, the pavement roughness at initial construction is taken as baseline parameter, and GHG emissions from fuel consumption are calculated based on the progressive increase from that initial roughness. This means that only the fraction of rolling resistance due to the increase of roughness, not its whole amount during the life cycle, is evaluated.

- The authors found that the majority of emissions occur during materials production and transportation (64%-80% on all roads) (see Figure 5). In particular, cement production has the largest GWP contribution on all roads: from 43% on urban interstates to 56% on rural local roads;
- The second largest contribution derives from fuel consumed due to the increase of the rolling resistance for high traffic roads (both rural and urban). For local roads (both rural and urban) EoL disposal was the third largest contribution. In the analysed case studies, congestion (traffic delay) and construction activities were less important;
- A sensitivity analysis has shown that the results were most sensitive to traffic flow (varying the results by up to 60%), design parameters affecting cement emissions (*i.e.*, shoulder width, lane width), aggregate transport distances and the pavement roughness value. From smaller to larger roads the results become more sensitive to rolling resistance. For smaller roads pavement design characteristics, carbonation, albedo and aggregates transportation are more important.

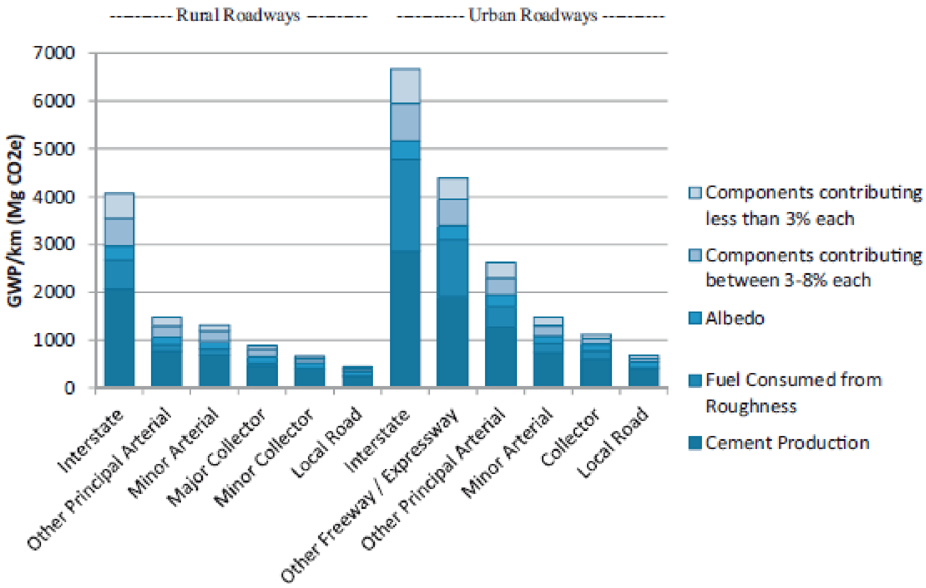


Figure 5: Life cycle GWP per km of new concrete pavements for 12 roadway classifications (Loijos *et al.*, 2013).

The results explained above conclude that there is a relevant parameter involved in the potential decrease of fuel consumption due to the interaction pavement-vehicle: the traffic flow. For high-traffic flow roads (>2000 vehicles per day), these losses became an important factor that justifies the measures aimed at reducing them. For low-traffic roads (<2000 vehicles per day), the fuel consumption during use phase turns to be comparable to other life cycle phases.

The parameters that might be potential indicators of the pavement – vehicle interaction are the following:

- Rolling resistance;
- Texture;
- Unevenness (longitudinal and transversal);
- Surface defects.

Rolling resistance

Currently there is no standardized method for determining the pavement contribution to rolling resistance. EU FP7 projects like MIRIAM and COOEE investigate the possibilities of using trailers for the monitoring of rolling resistance as a road surface property in analogy to skid resistance or noise emission, but those methods are not validated. The function that relates rolling resistance to texture and unevenness parameters needs to be developed enough in such way that rolling resistance could be controlled by managing these primary pavement properties, as MPD (mean profile depth) and IRI (International Roughness Index).

Practical factors related to rolling resistance must also be considered. For example, lower rolling resistance is **undesirable** in areas were vehicles have to decelerate due to the requirement for increased braking energy/distance. Therefore low rolling resistance surfaces should not be specified in any areas with frequent stop-start traffic flows and only be specified where they can be most beneficial, which is in high traffic volume road sections with steady or accelerating traffic flows most of the time.

Texture

According to Sandberg *et al.* (2011), macrotexture, represented by the parameter MPD (mean profile depth), is a major factor influencing rolling resistance.

The ISO 13473-n series of standards covers the measurement of pavement texture with profilometers and associated indices. All indices are based on filtered longitudinal height profiles of the pavement surface typically recorded with a mobile or stationary laser profilometer.

The most commonly used parameter is the MPD (mean profile depth) defined in ISO 13473-1 for an evaluation length of 100 mm. It is designed to indicate the typical elevation of profile peaks above an average profile baseline.

The texture wavelength ranges that contribute to a deformation of the tyre and induce rolling resistance losses are mainly in the macro and megatexture.

According to the technical analysis, the macrotexture seems to be a parameter that is expected to both decrease and increase during the use phase of the road, and its progression depends on the type of material, traffic flow and composition (heavy traffic) and climate conditions, mainly related to wet and dry freezes (Wang, 2012). It was also found that Sweden was considering setting MPD thresholds for both maximum and minimum levels of acceptance of this parameter (COST 354). Therefore, the monitoring of the increase of this parameter during the use phase of the road seems to be reasonable to assess the level of performance in relation to the rolling resistance.

Sandberg *et al.* (2011) also studied the MPD calculated on an enveloped profile curve. The results showed that the enveloping improves the MPD correlation with rolling resistance. The author highlighted that enveloped MPD is so well correlated with rolling resistance that it will be difficult to find a better single or major variable for the purpose of quantifying the pavement influence on rolling resistance. The concept of enveloping can be explained by a tyre running on a textured road surface: it does not necessarily make contact with all points on the surface in its wheel path. This is, *e.g.*, the case when the texture shows deep and irregular “valleys” (such as on porous asphalt) or deep and relatively regular “grooves" (such as on transversally grooved concrete). The tyre is said to be "enveloping" the part of the surface with which it is in contact.

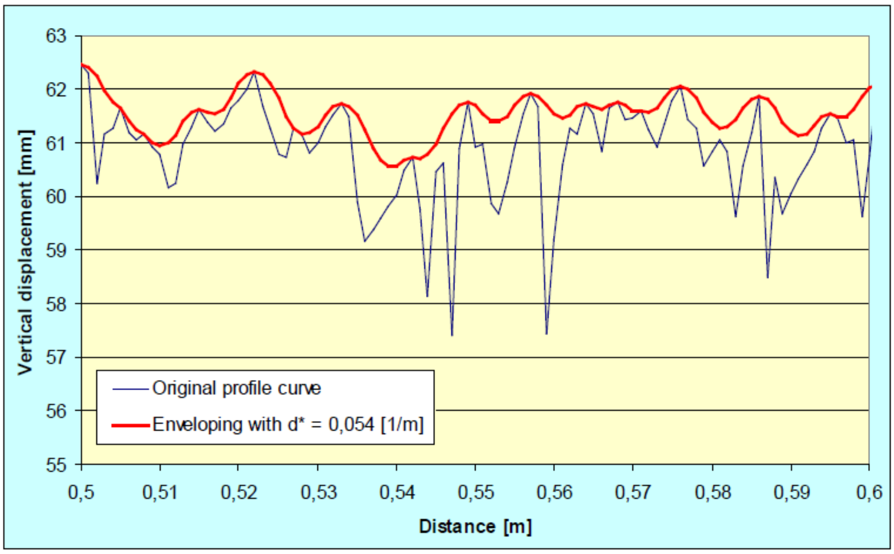


Figure 6: Example of enveloping method on a profile curve (Sandberg *et al.*, 2011).

Sandberg *et al.* (2011) explained several methods of enveloping, and set the von Meier method (von Meier *et al.*, 1992), using a tyre with an average stiffness (d*=0.054 m^{-1}) as a good first approach to be used in the MIRIAM project. Nevertheless, the author pointed out that the enveloping procedure should be studied and tested more widely, to come up with a test easy to apply producing reliable enveloping results.

Longitudinal unevenness

It contributes to the overall road vehicle energy consumption via three mechanisms:

1. The longitudinal unevenness of pavements contributes to the rolling resistance of the tyre but in a smaller degree than texture;
2. Longitudinal unevenness induces vibrations in the wheel suspensions. These vibrations have to be reduced to ensure ride comfort, which results in a conversion of mechanical energy into heat energy;
3. High levels of longitudinal unevenness will induce drivers to reduce the vehicle speed.

The induced vertical oscillations lead to energy conversion into heat, and thus they should be considered when modelling the energy losses due to the interaction vehicle-pavement.

The European standard prEN 13036-5 "Road and airfield surface characteristics – Test methods – Part 5: Determination of Longitudinal Unevenness Indices", specifies the measurement of longitudinal unevenness and the calculation of unevenness indices. It requires the measurement of a longitudinal road height profile with a sampling interval of 0.05 m. This profile is the basis for the calculation of different possible unevenness indices. The most common index is the IRI (International Roughness Index), which is intended to represent the reaction of a specific quarter-car model (golden car) to the road Infrastructure effects on vehicle energy consumption profile.

Other parameters

- *Transversal unevenness*

  The road surface will also exhibit deviations from this ideal transversal profile in the form of ruts, steps, ridges, bumps and edge slumps.

  Both crossfall and transversal unevenness might induce an increase in vehicle fuel consumption. Transversal unevenness can act similar to longitudinal unevenness by inducing increased tyre deformation and suspension losses.

  The measurement of transversal unevenness is defined in EN 13036-6 and EN 13036-8. While no specific measurement device is prescribed, typically a straightedge or a laser profilometer is used. The parameters used to describe the transversal unevenness are the rut depth, the height of the different irregularities and the theoretical water film depth for water accumulating in the ruts. These parameters are typically determined every 5 to 10 m and averaged for longer intervals of, *e.g.*, 100m. Crossfall and rut depth typically constitute the major deviations from an ideal horizontal road surface and are therefore the best candidates for the inclusion in models. The main parameter used for transversal unevenness is average or maximum rut depth.

- *Surface defects*

  Surface irregularities as joints or surface defects like cracks, ravelling, potholes, loss of material may influence on longitudinal and transversal unevenness, and on texture. Therefore, the impact due to these surface defects is related to the parameters associated with these surface properties. However, in the case of severely damaged surfaces there may be additional energy dissipation.

  The above mentioned parameters for longitudinal and transversal unevenness would be indicators of the degree of damage, but other ones as the area or longitudinal density of surface defects could be defined. A classification of relevant surface defects in the course of already performed crack detection surveys could be defined to take into account the predicted impact of the identified type of surface defect on fuel consumption, thus, it would work as an indicator for the predicted additional fuel consumption.

  Another parameter that is related to the surface defects on the road pavement is the durability (lifetime) of the material, since they are caused by damages during the use phase of the road along its lifetime. Therefore, the durability of the material, together with the designed lifetime of the road, could become a factor to be considered to prevent the maintenance needs of a road.

- *Deflection*

  Haider includes bearing capacity and deflection as parameter that might increase the rolling resistance. The study mentioned the research by Schmidt, Bjarne, Ullidtz, Per (2010) that compared the deformation of the road pavements as measured by FWD to the effects of rolling resistance. It was found, that rolling resistance due to pavement deformation was only a few percent of the overall rolling resistance, which is a much lower impact that the effect of e.g. texture. If very accurate models will be available in the future, they may have to take this effect into account at least for very weak road pavements.

  Sandberg *et al*. (2011) also point out stiffness as a parameter that might influence the rolling resistance. However, the study refers to the lack of stiffness data, meaning that just proxy variables might be found. This study does not quantify the effect of stiffness.

  Akbarian, Gregory, Ulm (2013) studied the effect of deflection on fuel consumption in the US roads. They compared the impact of deflection on passenger cars and trucks on concrete and asphalt pavements, and the results where the following: considering that an internal combustion engine vehicle performs a mean fuel consumption in the range 5 – 10 l/100 km for passenger cars, that would mean that deflection effect contributes between 0.4 – 0.2% of rolling resistance for concrete pavements and 2.4 – 1.2% for asphalt pavement. In the case of trucks, the weight of the vehicle varies within a very wide range, and for heavy trucks, deflection effect contributes on a larger scale (see Table 2).

Table 2: The impact of deflection compared to a rigid (non-deflecting) surface on fuel consumption applying the deflection contributions to real world road conditions from the LTPP database (Akbarian *et al.,* 2013).

	Concrete	Asphalt
	Mean (Std. Deviation) [liters/100km]	Mean (Std. Deviation) [liters/100km]
Passenger Cars	0.002 (0.0016)	0.012 (0.009)
Trucks	0.013 (0.012)	0.077 (0.06)

Rolling resistance and fuel consumption as a function of pavement-vehicle interaction parameters

A study of relevant literature has provided relationships between IRI and rolling resistance as well as fuel consumption. Tan *et al.* (2012) present a very comprehensive collection of data regarding pavement roughness effects on rolling resistance and fuel consumption. Results from studies from USA, Brazil, United Kingdom, France, Belgium, Sweden, South Africa, Australia and New Zealand are presented to show the change in rolling resistance and fuel consumption based on change in IRI. The studies include a wide range of IRI values, and data is provided for passenger cars as well as for trucks. New (European) roads will be expected to have IRI values below 6. This means that basically all data in Table 3 are applicable for European conditions.

Table 3 below shows that rolling resistance increases by 2.5-6% per unit IRI (cars) and by 1.8-4.4% per unit IRI (trucks), respectively. The studies report an increase in fuel consumption of 0.4-6% per unit IRI for cars and 0.13-4.1% per unit IRI for trucks, respectively.

Table 3: Uneveness effects on rolling resistance and fuel consumption (based on Tan et al., 2012).

Country/Source	**IRI range**	**Vehicle type**	**Rolling resistance**	**Fuel consumption**
			(% change per unit IRI)	(% change per unit IRI)
USA/Ross	0.5-3.7	Car	-	0.4
USA/Bester	1.4-5.5	Car	2.6	0.5
USA (Florida)/Jackson	3.1-3.7	Truck	-	0.13
USA (Nevada)/Epps et al. and Sime and Ashmore	3.1-3.7	Truck	-	0.45
USA/Zaabar and Chatti	1-5	Car (medium) Car (SUV) Truck (articulated)	- - -	0.9 0.4 0.6
Brazil/Watanatada et al.	2-14	Car Truck	2.5 1.8	0.5 0.5
UK/Young	1.3-4 3.3-5.6 2.3-4.4 1.7-5.4	Truck Car Car Car	- - - -	4.1 3.1 3.6 1.8
France/Laganier and Lucas	1-6	Car	6.0	1.2
France/Delanne	Not specified in IRI	Car	-	Up to 6
Belgium/Descornet	0.8-7.7	Car	4.0	0.8
Sweden/Sandberg	1-6	Car	-	1.6
South Africa/Du Plessis et al.	1.2-1.5	Car Truck	3.4 4.4	0.7 1.1
Australia/BTCE	1.2-5.8 1.2-5.8	Car Truck (rigid) Truck (articulated)	- - -	0.9 1.4 0.9
New Zealand/Jamieson and Cenek	1.7-5.3	Truck	-	0.8

Hammarström (2012) evaluated the influence of several variables on the vehicle energy consumption, based on the EVA model (a model to estimate the fuel consumption of vehicles) and the data of the Swedish Transport Administration. The variables to be included directly or indirectly in fuel consumption (Fc) functions in the EVA model are the following:

- road surface variables: IRI and MPD;
- road alignment: gradient and horizontal curvature (see Table 4);
- speed;
- acceleration;
- transmission;
- engine internal friction.

Table 4: Road alignment standard for EVA roads (Hammarströn, 2012).

Type road	Length (m)	Sight class	*ADC* (°/km)	*RF* (m/km)
LF_typ11	22 989	1	1.53	5.49
LF_typ12	22 009	2 (straight, rolling)	9.80	15.36
LF_typ21	20 893	2 (sinuous, plane)	29.8	5.00
LF_typ22	21 477	3 (sinuous;rolling)	17.47	17.56
LF_typ3x	25 149	4 (sinuous;rolling)	85.63	18.28
LF_typx3	24 575	4 (sinuous, hilly)	42.43	28.98

Note: ADC: Average degree of curvature; RF: Rise and Fall (Gradient); LF_typXX is the code used to name the type of roads.

The study also addressed the influence on speed from other conditions not included in the EVA model. This influence includes at least the following parts:

- if the tractive force is bigger than the maximum engine wheel force there will be a speed reduction compared to the desired EVA model speed;
- IRI and rut depth influence on desired speed.

Based on the results of the model applied, the study analyses how the total fuel consumption (Fc) changes if road surface measures are reduced. If MPD per road link is reduced by up to 0.5 mm, the total Fc in the transport administration road network will be reduced by 1.1%. By reducing IRI per link by 0.5 m/km, speed will increase in parallel to reduced rolling resistance and there will be approximately no resulting effect on Fc. If rut depth is decreased in parallel to IRI there will be a further increase in speed. For individual road links there might be energy saving potential related to IRI if the proportion of heavy vehicles is big enough.

For a car, a speed reduction of 1 km/h at SCL 1 (sight class 1) standard will decrease Fc by 0.7% in a wide speed range. To compare: if the average MPD is reduced by 0.25 mm car Fc will be reduced by 0.6%. The study shows that an improvement of the alignment standard (not worse than SCL 2) in the transport administration road network could bring fuel consumption savings by 1–2%.

In summary, the conclusions of the study related to the road surface parameters are that a reduction of IRI by 0.5 and MPD by 0.5 is expected to change total Fc by:

- 0.0% for just IRI;
- -1.1% for just MPD;
- -1.1% for both IRI and MPD.

The study found out that a reduction of Fc could be achieved by means of a decrease of IRI just for heavy trucks with trailers (Figure 7).

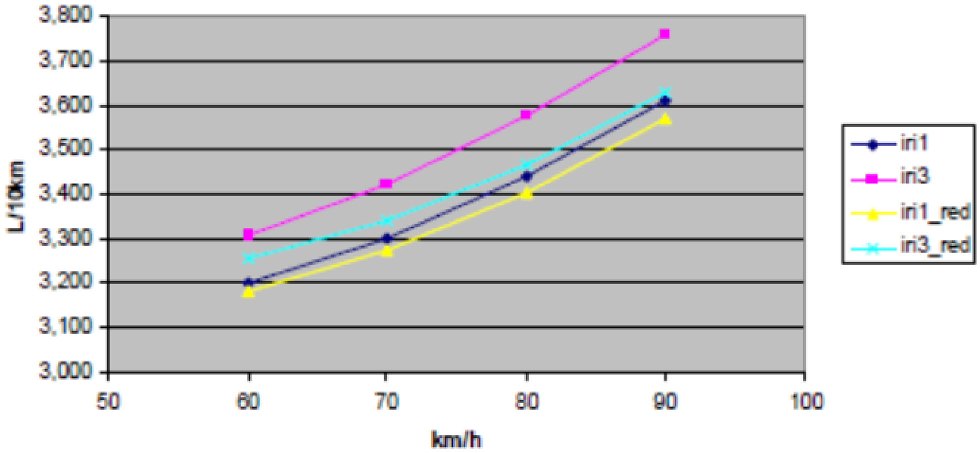


Figure 7: Fc with (_red) and without an IRI speed effect for a truck+trailer. Diagram x-axis speed excluding the IRI adjustment (Hammarströn, 2012).

As a result of this analysis, the road alignment can be identified to be the most relevant variable to decrease the fuel consumption. The increase in Fcs from sight class 1 to sight class 4 is estimated as 2.4% including the speed effect. Nevertheless, the paper also concludes that the improvement of the MPD of a road is easier to achieve compared to an improvement on the road alignment. In this regard, the potential of fuel consumption associated to the road alignment should be assessed at the planning phase of the project.

These conclusions are endorsed by the outcomes of the WP2 of MIRAVEC project (Carlson, Hammarström, Eriksson, 2013). The report shows that in general, among road variables, rise and fall/gradient leads to the largest impact on fuel use, followed by MPD and average degree of curvature. A speed effect for IRI and RUT offsets fuel use savings to some extent (see Figure 8).

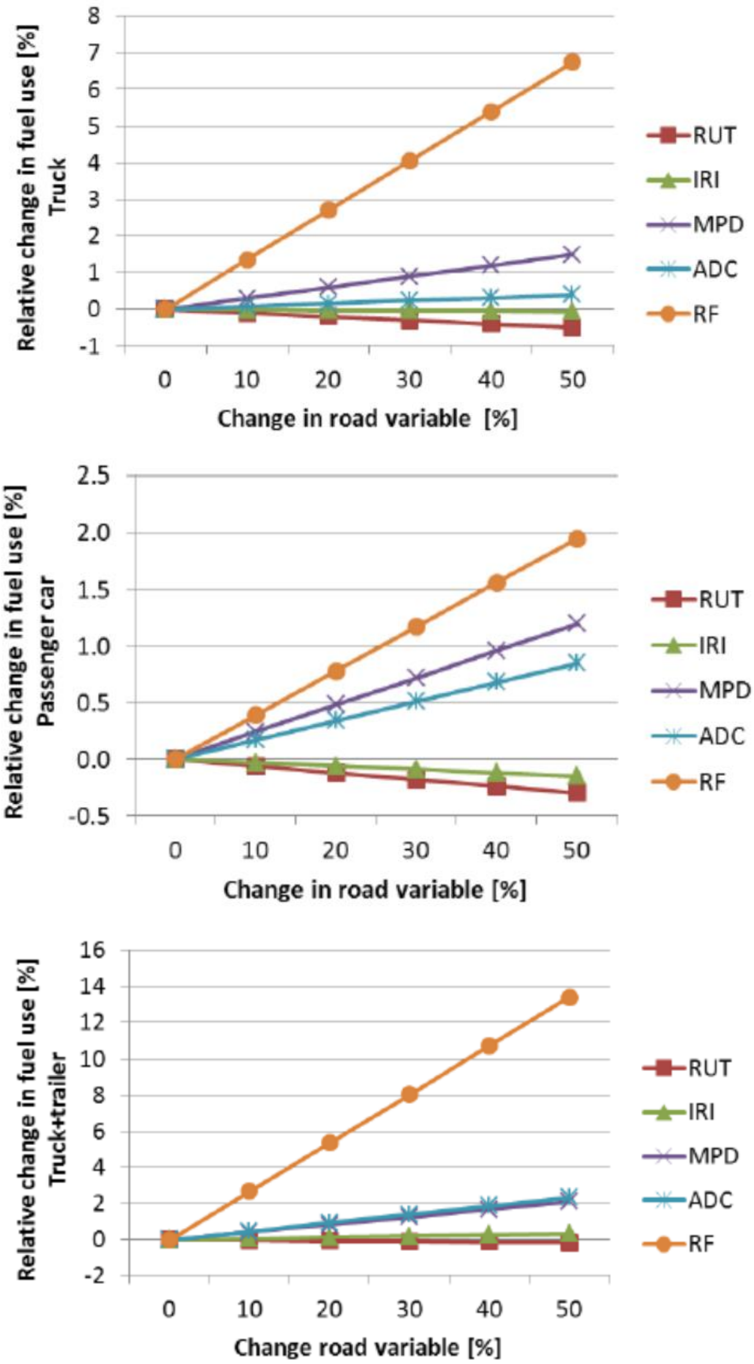


Figure 8: Sensitivity of passenger car and truck fuel consumption to changes in infrastructure parameters for rise and fall (RF), curvature (ADC), macrotexture (MPD), unevenness (IRI) and rutting (RUT) (Carlson *et al.,* 2013).

The comparison of the results of the studies carried out in US and the ones from the MIRIAM project clearly points out to divergent conclusions with regards of the influence of IRI on the fuel consumption. This difference could be explained by comparing the models used to predict the fuel consumption. The model developed by Hammarströn (2012) includes the speed effect, meaning the increase or decrease of speed due to the pavement conditions. Chatti and Zaabar (2012) used a model that seems not to include the speed effect.

Previous draft criteria area for rolling resistance and stakeholder consultation

As a preliminary step, it is recommended to evaluate the traffic flow planned during the road design. In the case of high-traffic roads (as motorways and highways), the parameters related to the pavement-vehicle interaction should be considered within the procurement process. For those roads expected to bear low traffic flows, it is advisable to focus on other criteria areas, as the improvement potential on the fuel consumption is not so relevant.

In addition, lower rolling resistance is **undesirable** in areas were vehicles have to decelerate due to the requirement for increased braking energy/distance. Therefore low rolling resistance surfaces should not be specified in any areas with frequent stop-start traffic flows.

The parameters to evaluate the pavement are commonly used by the public administrations (as National Road Administrations – NRAs – or regional/local authorities) in the design, construction, monitoring and maintenance phases, but they are usually assessed only under safety and comfort requirements. The rationale shows that an evaluation under an environmental perspective, focused on fuel consumption, should be integrated in the decision-making process about those parameters along the design, construction and maintenance.

During the design phase, the design team, DB tenderer or DBO tenderer should take into account the MPD and the durability associated to the construction materials to be used in the pavement. Some options would be to set a MPD performance, within the safety range of values demanded by the road, and to select the most durable materials for the particular needs of bearing capacity calculated for the road.

Before the opening of the road, the verification about the materials used in the pavement and the parameters related to the texture should be carried out by the procurers, taking into account the standardized methods to measure MPD.

The monitoring and routine maintenance are key issues in this criteria area. Both activities are usually carried out by the public authority, in-house or by mean of maintenance service procurement. According to the rationale above, these activities should consider the fuel consumption due to the increase of the MPD, the unevenness and the surface defects, thus the monitoring of those parameters associated are recommended to be linked to thresholds or ranges that trigger the maintenance actions aimed at returning those parameters to the optimal values. These target values define the optimum condition to be achieved after maintenance measures. Threshold limits for MPD might be defined by a range between minimum required values for skid resistance and maximum desirable values for limiting fuel consumption via reduced rolling resistance.

It has been found that the most important factors that influence the rolling resistance are the macro-texture and megatexture, thus, it is recommendable to set thresholds to the MPD of the pavement together with a monitoring frequency. A maximum interval for monitoring is recommended (in literature 5 years are suggested).

The results of MIRIAM and MIRAVEC projects reflect that IRI is not so relevant to save fuel consumption of cars and heavy trucks, showing potential savings just for heavy trucks with trailers. This is also in line with the comments received from the stakeholders after the 1st AHWG meeting. Therefore, it is proposed that just MPD is taken into account as pavement-vehicle interaction parameter to save fuel consumption in the use phase.

MPD and skid resistance

Some stakeholders have raised their concerns about the effect of a low macrotexture on the skid resistance of the road surface, and how a potential criterion on MPD jeopardizes the safety performance of the road (see Figure 9). This issue has been addressed by several European projects, *e.g.*, Tyrosafe. The deliverable D14 of this project, Interdependencies of parameters influencing skid resistance, rolling resistance and noise emissions (Sharnigg, 2010), studies the effect of MPD and IRI, among other parameters, and the potential conflicts between those effects (see Figure 9 and Table 5).

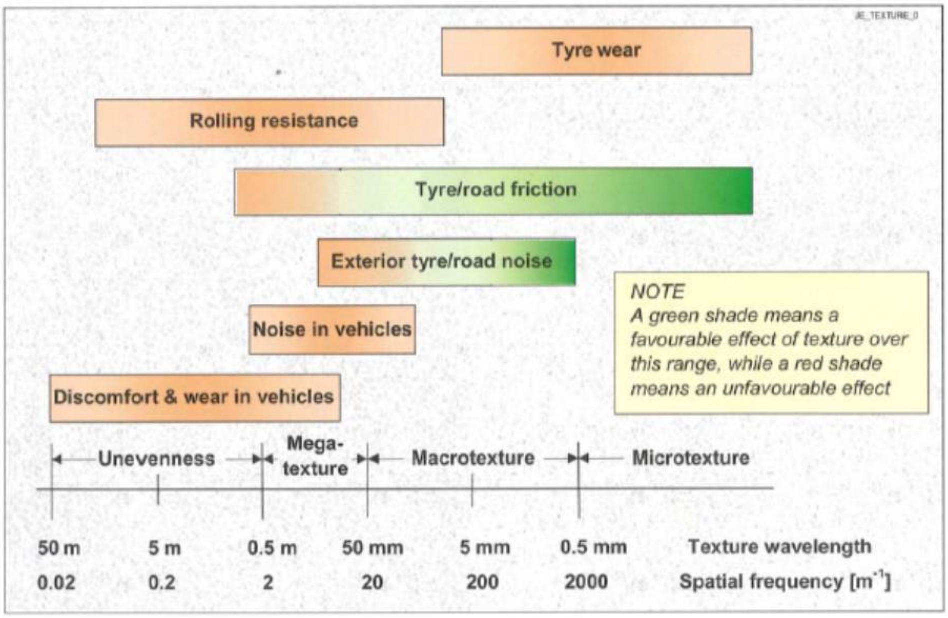


Figure 9: Effects of the texture wavelength of road surfaces (Sharnigg, 2010).

Table 5: Interdependency matrix of surface parameters (Sharnigg, 2010).

			Skid Resistance		Rolling Resistance	Noise Emission
asphalt						
aggregate properties	• shape of aggregates (SI/FI)	↓	+	o[1]	?	+ [2]
aggregate properties	• angularity of aggregates	↑	+		?	o
aggregate properties	• polishing resistance (Polished Stone Value (PSV)/coarse aggregates)	↑	+[2]		?	o [2]
aggregate properties	• polishing resistance (PWS /fine aggregates)	↑	+[3]		?	o [2]
aggregate properties	• hardness	↑	+		?	?
aggregate properties	• aggregate composition and Structure (percent of hard fraction by visual examination and petrographic analysis)	↑	+		?	?
aggregate properties	• abrasion/wear resistance (Micro Deval)	↓	+		?	?
mixture parameters	• maximum aggregate size	↓	+[4]		+	+
mixture parameters	• binder content	↓	+	-	?	?
mixture parameters	• binder type (viscosity)	↑	+		+	+[5]
mixture parameters	• void content (mix design)	↓	-	+[6]	+	-

[1] Depends on the composition used, according to EN 13108-1, -5, -6, -7 (AC, MA: o, SMA, PA: +)
[2] On mastic asphalt, according to EN 13108-6, it can take a long time for the aggregates to become exposed to the contact area of the tyre; consequently, these properties do not have a positive effect on skid resistance until later in the service life.
[3] As with coarse aggregate, on mastic asphalt according to EN 13108-6 it can take a long time for the aggregates to become exposed to the contact area of the tyre; consequently, these properties do not have a positive effect on skid resistance until later in the service life.
[4] On mastic asphalt according to EN 13108-6, there is no known impact of the aggregate size used.
[5] Rubber modified binder may have a positive effect on noise reduction
[6] Only in dense asphalt mixtures; not in porous asphalt mixtures

			Skid Resistance	Rolling Resistance	Noise Emission
laying and compacting	• chippings – aggregate size	↓	+	+	+
	• chippings – PSV/PWS	↑	+	?	o
	• degree of compaction	↑	?	?	-
concrete					
aggregate properties	• shape of aggregates (SI/FI)	↓	?	?	+
	• angularity of aggregates	↑	+	?	o
	• polishing resistance (Polished Stone Value (PSV)/coarse aggregates)	↑	+	?	o
	• polishing resistance (PWS /fine aggregates)	↑	+	?	o
	• hardness	↑	?	?	?
	• aggregate composition and structure (percent of hard fraction by visual examination and petrographic analysis)		?	?	?
	• abrasion/wear resistance (Micro Deval)	↓	?	?	?
mixture parameters	• maximum aggregate size	↓	+	+	+
	• water/cement-ratio	↑	?	?	?
	• stability of the concrete	↑	-	?	?
	• consistency	↑	+ / -	?	+ / -
	• additive		?	?	?
laying	• thickness of the surface mortar	↑	?	?	?
	• surface textures – exposed aggregate concrete	-	+	?	+
	• surface textures – burlap	-	-	?	+
	• surface texture – brushed concrete surface	-	+	?	+ / -
	• texture depth - mean texture depth (MTD)	↑	+	-	+ / -
miscellaneous					
finished surface	• surface type (asphalt or concrete)	asphalt	o	?	+[7]
	• damper function of the base layer	-	?	-	+
	• shape factor (g)	> 70%	?	?	+
	• characteristic shape length (g')	400–700 mm	?	o	+
	• maximum of the spectral roughness depth (R_{max})	60-200 µm	?	?	+
	• absorption	↑	o	o	+
	• layer thickness		o	o	+ / o[8]
	• flow resistance	↑	o	o	+
	• further texture parameters (micro- / macrotexture) – see Figure 2.1 and also Figure 5.1	↑	+ / +	o / -	+ / -[9]
	• unevenness	↑	-	-	?

[7] In [56] it was found that a dense concrete surface with chippings (e.g. 5 mm maximum stone size) created a surface which was about 2 dB(A) louder than the same chippings used on an asphalt surface. This effect derives from the higher internal damping of asphalt compared with concrete.
[8] On porous surfaces; on dense surfaces the layer thickness has no impact on noise reduction
[9] *At high frequencies:* the increase of the texture amplitudes at wavelengths in the range 0.5 to 10 mm (microtexture) may reduce noise generation, particularly at frequencies generally above 1 kHz. *At low frequencies:* the increase of the texture amplitudes at wavelengths in the range 10 to 500 mm (macro texture) causes an increase of noise, particularly at frequencies below 1 kHz.

At first sight, optimising primarily for safety implies designing road surfaces with parameters that maximise skid resistance. To do this, by maximising macrotexture for example, could lead to noisier surfaces with increased rolling resistance.

Tyrosafe report mentions a texture depth of 0.4 - 0.8 mm at wavelength of 0.5 - 10 mm as potentially leading to improve the three properties: noise emissions, skid resistance, rolling resistance. Nevertheless, it is also highlighted that the optimal solution in a particular situation might mean focussing on just one or two of the main surface properties rather than all three at once, to be decided case by case. It was found that a smaller set of parameters could be used as the basis of optimising road surfacing performance in relation to the three main properties and these have been used to suggest what properties an optimised road surfacing might have, namely:

- low aggregate size (5 or max. 8 mm);
- polishing resistance appropriate to the expected traffic and skid resistance level required over the life of the surfacing;
- high angularity of aggregates;
- cubic shape of aggregates;

- binder viscosity optimised for the application (preferred polymer modified bitumen);
- a concave surface texture (without separately applied surface chippings for asphalt or an exposed aggregate form for concrete).

Some comment from stakeholders also pointed out that lowering the maximum aggregate size might bring good results both for skid resistance and rolling resistance.

Therefore, any endeavour to propose a well-balanced threshold of MPD as a GPP criterion needs to be framed within the safety conditions legally required for the skid resistance. These safety requisites depend on multiple variables: climatic conditions, speed limits, rise and fall profiles, traffic intensities, *etc*.. Thus, Tyrosafe report recommends defining a common EU legal framework that should be further developed and applied at local level. In this regard the COST report gathered information about different limits on MPD across EU countries. The report collected few answers from the countries, but the range of 0.75 to 1.5 mm of MPD seems to be considered as 'very good' in terms of skid resistance for motorways and other primary roads. The figure of 0.64 mm is the 'warning limit' in the Czech Republic, while a value of 0.54 mm triggers obligatory maintenance measures due to safety concerns.

One comment pointed out the concerns related to wet friction and low macrotexture. The MIRAVEC report Deliverable 4.1 *Recommendations for implementation of road vehicle energy consumption in pavement and asset management systems* (Kokot and Stryk, 2013) identified wet friction as a serious trade-off associated to low macrotexture. Low wet friction is caused by the combination of low macrotexture and high speeds, but macrotexture may be high without negative influence on rolling resistance, provided the profile is negative (negative skewness).

Sandberg *et al.* (2011) studied the effect of skewness in rolling resistance. Skewness is a dimensionless measure of asymmetry of the amplitude distribution. This indicates whether the profile curve exhibits a majority of peaks directed upward (positive skew) or downward (negative skew). For a normal distribution, skewness is equal to zero. The Figure 10 shows the differences between possible and negative skewness.

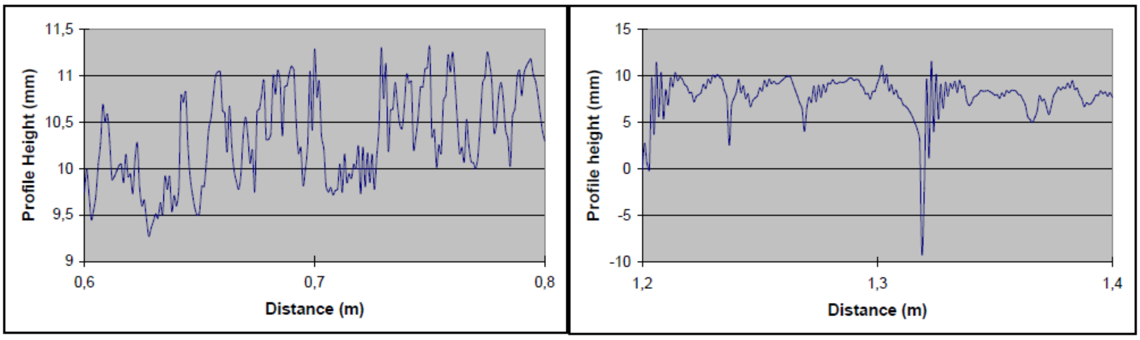


Figure 10: Skewness of the left profile would be positive while it would be substantially negative for the right profile (Sandberg *et al.*, 2011).

MPD as defined in ISO 13473-1 is a measure where the peak values occurring in the segments have a more important weight than the valleys, and therefore, the MPD value is sensitive to the asymmetry of the profile. Nevertheless, Sandberg et al (2011) evaluated the correlation between skewness and MPD, concluding that MPD does not fully describe the asymmetry of the profile.

The enveloped MPD would be an alternative parameter to distinguish the different effects of positive and negative skewness on rolling resistance. A macrotexture with a negative profile can result in a high 'normal' MPD with no trade-offs on wet friction, while resulting in a low enveloped MPD and low rolling resistance. In this regard, Sandberg *et al.* (2011) recommended a further study on the enveloping procedures and its standardization.

The replies from the stakeholders to the question about setting a threshold on MPD resulted in a split view between those who think it is not feasible due to the lack of robust data and models and the possible conflict with safety requirements, and those who consider it appropriate provided that the life cycle costs are optimized. Other concerns are related to the verification, since MPD might vary considerably along a road section, plus the level of accuracy of measuring / monitoring equipment should be agreed.

Change of MPD over time

The evolution of the MPD of the road surfaces is also a subject to be taken into account when designing a criterion on road surface performance. An overview of the common practice across the EU has shown that MPD is generally prone to decrease with the road aging due to the polishing effect of traffic. Within the maintenance strategies, there is a threshold for skid resistance that triggers the actions to recover the target values, together with a monitoring frequency using test methods as Grip Tester, Skid Resistance Tester (SRT), ROAR and SCRIM. This does not necessarily mean that MPD decreases with the road aging in all cases. The study from Wang *et al.* (2012) shows that MPD could also increase under specific climate conditions.

Liang (2013) analysed the evolution of MPD, and one example of the results is provided in Figure 11:

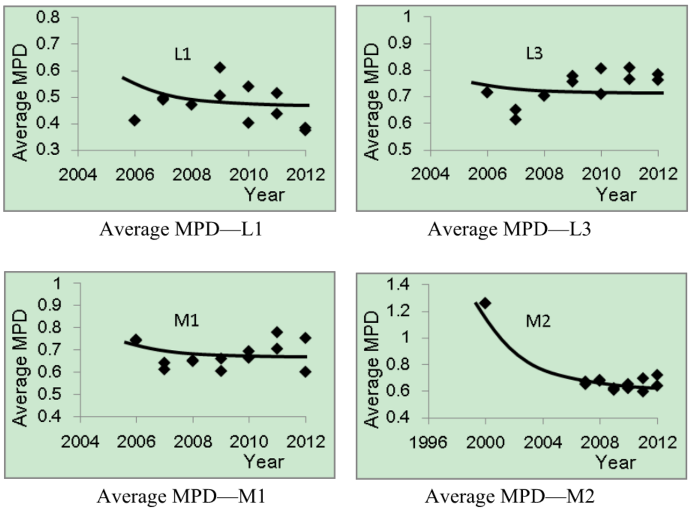


Figure 11: Mean Profile Depth pavement texture degradation as a function of time. Four different test sections monitored over 6 years. All test sections are flexible (hot mix asphalt) and located in Ohio, USA (Liang, 2013).

Curves like the ones shown in Figure 11 are important for pavement management systems in order to predict pavement performance and hence future needs for pavement maintenance and rehabilitation.

Degradation curves can also be used to predict user costs by applying among others the relations between IRI and fuel consumption mentioned earlier. Fuel consumption is a very handy descriptor for user costs as it is easy to express fuel consumption in monetary terms.

The study "Influence of road surface type on rolling resistance" (Hooghwerff *et al.*, 2013) contains the results of a measurement program of MPD and RR on different roads in Netherlands. The measurement program consisted of a total of 69 road sections where both rolling resistance and texture measurements were performed simultaneously (main road sections). Different road surface types were measured, including: PAC (Porous Asphalt Concrete) 16, DLPAC (Dual Layer Porous Asphalt Concrete) 2/6, DLPAC 4/8, DAC (Dense Asphalt Concrete), TSL (Thin Surface Layer), SMA (Stone Mastic Asphalt) and SD (Surface Dressing). The selected road surfaces vary both in age and maintenance condition. Most of the PAC and DLPAC road sections were measured on highways, while TSL and SMA were primarily measured on provincial roads in the province Gelderland. All the measurements were conducted between April 17th and April 23rd, 2013.

The results show that the effect of aging in MPD seems to be most apparent for Dense Asphalt Concrete surfaces for which older roads perform higher MPD values, while for other surfaces there is no clear age effect. One comment from the stakeholders also pointed out the results of this study.

Nevertheless, the effect of polishing is determining to define a criterion on low MPD, since a threshold too close to the 'warning' levels for safety conditions would demand more frequent maintenance actions, and thus, an increase of energy consumption. Likewise, this will happen if the materials chosen to lower the MPD are less durable. Therefore, a holistic evaluation, based on LCA and LCC analysis, should be applied, as suggested by the stakeholders.

In this regard, MIRAVEC D4 deliverable "Recommendations for implementation of road vehicle energy consumption in pavement and asset management systems" (Kokot and Stryk 2013) summarizes the results of some studies that investigate the rolling resistance from a life cycle perspective:

VTI report (Karlsson, 2012) is the outcome of the Swedish studies performed under Sub-project 3 of the MIRIAM project. The objective was to investigate the role of RR on the total energy use and if maintenance treatments can be a viable option to reduce the total energy use. The results show that lower values of rolling resistance lead to energy savings in those roads with high traffic flows, becoming more relevant when the proportion of heavy vehicles is larger.

The paper produced at the University of California Pavement Research Center (UCPRC) (Wang et al., 2012) describes a Lifecycle Cost Analysis (LCA) model developed to evaluate energy use and GHG emissions from pavement rehabilitation strategies. The LCA model includes the effects of pavement rolling resistance on vehicle operation which was demonstrated on few case studies. The LCA model presented uses the framework and approach described in the developed Pavement LCA Guideline. For pavements, the life cycle includes material production, construction, use, maintenance and rehabilitation (M&R), and end-of-life (EOL) phases.

LCA includes an alternative and novel method to evaluate the use phase of pavements, incorporating both roughness (unevenness) and macrotexture (described by IRI and MPD/MTD, respectively) as indications of the pavement surface condition. The rolling resistance is then calculated based on the HDM-4 model and used to estimate the increased engine load experienced by cars and trucks due to additional rolling resistance. The system was recently calibrated to North American vehicles through project NCHRP 1-45.

HDM-4 can also be used to consider the effects on rolling resistance caused by pavement deflection; however, because the calibration from NCHRP 1-45 indicated that pavement deflection was only significant when heavy trucks were moving at slow speeds on hot asphalt it was assumed that energy consumed by deflection would be zero.

In HDM-4, the rolling resistance is calculated based on the following factors: IRI, MTD, deflection, climatic factor, and characteristics of vehicles, tyre type, speed and a set of coefficients.

With this analysis, it is possible to evaluate the cost-effectiveness of maintaining smooth pavements compared to other strategies already underway to reduce GHGs from the highway transportation sector. The models will next be used by the research team to assess smoothness specifications for Caltrans highways with different levels of traffic, and M&R trigger levels for IRI and ravelling (MPD for asphalt) and traffic level based on their impact on GHG emissions and energy consumption.

The results of this paper show that the maintenance strategy to improve the smoothness of a road surface yields to energy savings in the case studies where the AADT is high (the case study BUT-70, whose AADT is 3200, does not result in energy savings) and the proportion of heavy vehicles is above 25%.

Table 6: Life cycle energy and GHG saving compared to Do Nothing over the analysis period under 0% traffic growth with Smooth rehab strategy.

Case study (analysis period)	Material	Feedstock energy (10^6MJ)	Material production (Average value, 10^6MJ)	Construction (10^6MJ)	Use (10^6MJ)	Total energy saving (10^6MJ)	GHG reduction (Metric tonCO_2-e)
KER-5(5 years)	HMA	−33	−20	−7.0	100	74.7	5,283
	RHMA	−49	−18	−5.4	100	77.9	5,733
BUT-70 (5 years)	HMA	−17	−9.8	−3.6	4.7	−8.7	−695
	RHMA	−24	−9.1	−2.7	4.7	−7.1	−471
LA-5 (10 years)	Type III cement	0	−9.4	−4.4	550	530	38,136
	CSA cement	0	−7.3	−4.4	550	540	38,471
IMP-86 (10 years)	Type III cement	0	−4.7	−2.2	29	23	1,377
	CSA cement	0	−3.6	−2.2	29	24	1,544

MIRAVEC project Work package 3 (Benbow, Brittain, Viner, 2013) has developed a spreadsheet tool to estimate the fuel consumption associated to the use phase of a particular road, as a function of:

- Fuel consumption model for free flow traffic:
  - o Vehicle characteristics (type, fuel used, Euro class);
  - o Rolling resistance, Air resistance, Average degree of curvature, Rise and fall/gradient, Velocity;
- Rolling resistance dependent on ambient temperature, IRI, MPD;
- Vehicle velocity, based on posted speed, vehicle type, traffic volume, gradient, IRI and rutting present;
- Idle time.

The Miravec tool is capable to estimate the vehicle fuel consumption associated with a specific route and evaluate the effects of various changes to the road infrastructure on the fuel consumption.

The MIRAVEC tool estimates the average vehicle speed from the road geometry, the level of rutting and ride quality present, the level of traffic and the split of heavy to light vehicles. In addition, a simple method for estimating the effect of idle time due to traffic congestion has been developed and implemented. It further enables users to estimate vehicle fuel consumption associated with a specific route and to explore the effects of various changes to the road infrastructure on the fuel consumption. This spreadsheet tool has been used to assess the potential benefits to be gained from making improvements to the infrastructure (*i.e.*, the capacity for NRAs to provide energy reducing road infrastructure) by considering different scenarios and using statistical data available from national road networks.

WP3 found that most of the changes applied have small effects on the average CO_2 output per vehicle per km and therefore significant changes in the fuel consumption will be most easily achieved on lengths with high traffic levels. With multiple intervention options available to NRAs the effectiveness of each intervention will depend on the condition and traffic levels of the site. A good example of that is the introduction of an additional lane that can have a large impact on fuel consumption on sites where idle time/congestion is a significant factor, but this same treatment would have little or no impact on a site with lower traffic densities.

Monitoring and maintenance

As explained above, the MPD value of a road might vary due to the aging of the road pavement, therefore this criterion should be related to the maintenance and rehabilitation (M&R) strategies implemented for this road.

Nevertheless, feedback from stakeholders shows that there are concerns related to the evolution of the MPD given that it is very variable and dependent on climate and weather conditions, traffic intensity, *etc.*. This results in a high uncertainty for the tenderers to meet the requirements of durability and maintenance actions to fulfil the target thresholds of MPD, meaning that they cannot commit to comply over a period of time with the values (and the associated maintenance actions to keep the MPD within the target values) of a parameter whose evolution in time cannot be fully predicted.

For that reason, it is proposed to withdraw the requirement on durability of the performance parameters, which had been initially considered (5 years). The parameter MPD is very closely linked to the skid resistance, which is a safety parameter included in the monitoring plans implemented by the road authorities. One of the main risks identified is that the effect of polishing might demand more frequent maintenance actions, and thus, an increase in energy consumption. The most relevant parameter in this case is the skid resistance, which is monitored on a regular basis for safety reasons, and one of the main parameters which maintenance actions are aimed at. Consequently, the effect of the MPD is indirectly taken into account in the criteria Environmental performance (B.14) and Maintenance.

Direct measurement of rolling resistance

One of the experts participating in this criteria revision process advised to use the rolling resistance parameter instead of MPD. The MPD can then still be used as verification upon delivery as a proxy of rolling resistance, using the relation between rolling resistance and MPD. This alternative is now included as an option, allowing the integration of all parameters involved in rolling resistance (MPD, IRI, stiffness, air temperature, *etc.*).

There are different methods for the direct measurement of rolling resistance of road surfaces, but none has been standardized so far:

- Force or torque measurements in specialized trailers;
- Force or torque measurements in the wheel suspension or transmission;
- Coastdown measurements of vehicles including precise measurements of the (negative) acceleration;
- Measurements on drums fitted with a replica road surface;
- Fuel consumption measurements in closely controlled drive cycles.

The results of different programs of rolling resistance measurement are gathered in several reports within the MIRIAM project (Sandberg *et al.* 2012, Lundberg and Sjögren, 2012, Bergiers *et al.* 2011, Hooghwerff *et* *al.* 2013). The methods used in the MIRIAM project are mainly drum, trailer and coastdown. Even though there is no formal standard for rolling resistance, in some countries there is enough experience on the direct measurement of rolling resistance, which enables to develop suitable protocols for public procurement purposes, provided that they are validated according to ISO 17025.

Therefore, in the final criteria proposal, it is proposed to include this option to be chosen only if the following requirements are met:

1. the contracting authority sets the test method to be used for the direct measurement of rolling resistance in the ITT, and;
2. the tenderers have access to laboratories that test the rolling resistance according to that test method, and;
3. the test method is validated according to the provisions of ISO 17025.

In this regard, one of the experts currently working on the development of standards for the direct measurement of rolling resistance explained the possible evolution of the rolling resistance criterion applied to GPP, following the steps below:

1. an MPD criterion, based on current knowledge and with a view to safety limits imposed by skid resistance requirements;
2. a criterion based on rolling resistance derived from commonly measured parameters like MPD, IRI, through a validated model like VETO;
3. a criterion based on rolling resistance measured directly with a standardized test method.

The standardization of the direct methods to measure rolling resistance is one of the objectives of the currently ongoing EU FP7 ROSANNE project (http://rosanneproject.eu/).

Assessment and verification issues

The incorporation of the MPD parameter as part of a GPP criterion also raises doubts in relation to its assessment and verification, since the designed MPD value of the road surface is likely to entail errors and thus, deviations from the designed valued are likely to occur after the construction phase. One of the consulted experts provided relevant information about the measurement program carried out in the Netherlands. The range of MPD values measured is shown in the figure below.

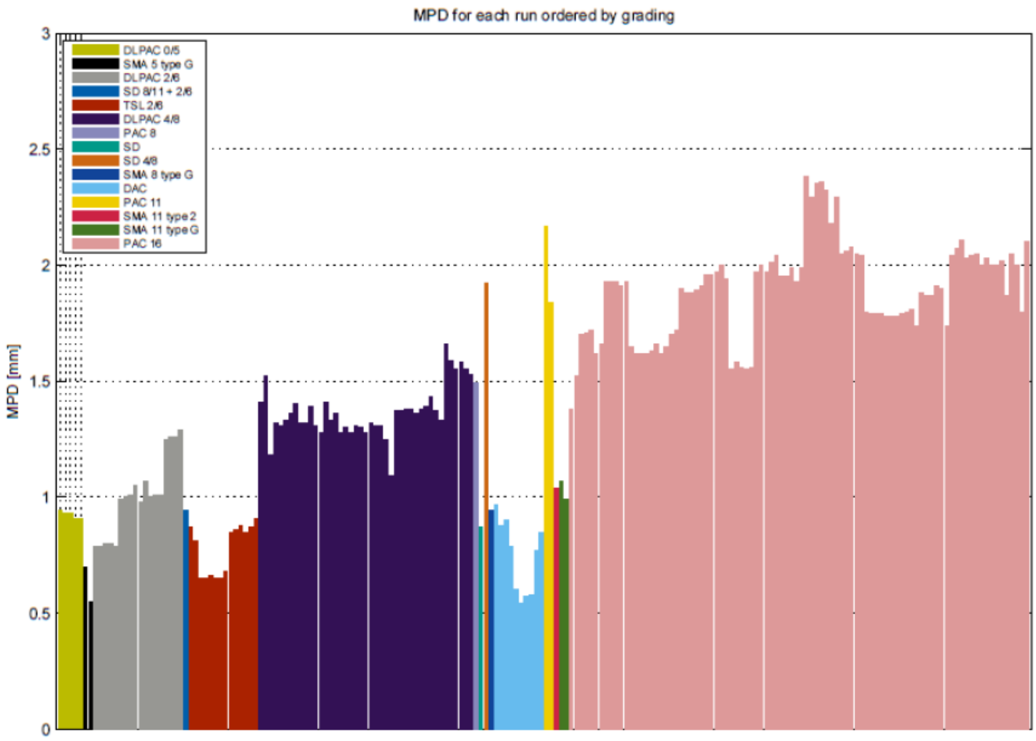


Figure 12: Results of the measurement program in Netherlands (Hooghwerff *et al.*, 2013).

The expert highlighted that the MPD deviation among roads with same surface texture can be large per pavement type, but the average MPD value per pavement type is significantly different from the other – especially so for PAC+ (pink) vs. DLPAC 4/8 (purple) and DLPAC 2/6 (brown). In the expert opinion, some of the measured variance is likely due to ageing, and for newly laid pavements the range of deviation should be smaller.

The expert advised to use the rolling resistance parameter instead of MPD. The MPD can then still be used as verification upon delivery as a proxy of rolling resistance, using the relation between rolling resistance and MPD. This option allows further investigation on rolling resistance and how it is correlated to the main surfaces parameters.

Another expert also explained that the obtained texture of a pavement depends on the mix design, aggregate size and bitumen content, so the MPD value could be anticipated based on those parameters. However the compaction method and pattern do play a significant role for the texture obtained, so some deviation is expected at the construction phase.

Formulation of the criterion proposal as comprehensive award criterion

It is proposed that this criterion is formulated as an award criterion, therefore non-mandatory and meant to stimulate additional environmental performance. It is formulated at the comprehensive level only, so it would be applied as an upper level of ambition to award points to best available technologies. Even though there are some doubts related to the maturity of the research, the background related to the MPD correlation is robust enough to formulate a criterion that has demonstrated to have a potential for energy savings that is worthwhile to be promoted. It is acknowledged that the experience on modelling and direct test methods of rolling resistance vary across EU countries, meaning that some frontrunners are fully prepared to use models and/or direct measurement of rolling resistance, while other contracting authorities may lack the knowledge to use those methods. For that reason, the criterion consists of different options to be chosen by the contracting authorities within the set of comprehensive criteria. The formulation of the criterion as technical specification has been ruled out, since there are neither absolute nor relative benchmarks for the parameters proposed (MPD, traffic fuel consumption and rolling resistance), only that their values must be within the boundaries set by the safety parameters (skid resistance and wet friction) of the road pavement. Considering the output of the literature reviewed (10% reduction in the rolling resistance can lead to 1-2% improvement in fuel economy according to Evans *et al.*, 2009, Tiax *et al.*, 2003 and Transportation Research Board, 2006; a reduction of 0.5 mm of the MPD value can produce a decrease of 1% of the fuel consumption according to Carlson, Hammarström, Eriksson, 2013) and the scale of the CO_2 emissions due to road transport (it contributes to the 20% of EU's total emissions of CO_2), any improvement in those parameters can be deemed significant.

2.2.2 Summary of feedback from the 2nd round consultation of stakeholders

Stakeholder feedback received after the 2nd AHWG

The main comments received from stakeholders during the 2nd AHWG and the 2nd round consultation can be summarised as following:

- There were concerns about this proposed criterion since the research does not seem to be mature enough;
- The comments also pointed out that the evolution of the parameters involved (*i.e.*, MPD) is very variable and dependent on climate and weather conditions, heavy traffic, *etc.*. Therefore, a requirement on durability of the MPD raised many doubts among the stakeholders, and the capacity of the contractors to control such unpredictable parameter;
- It was also recommended to use the direct measurement of rolling resistance, instead of the indirect measurements of MPD, to have a more accurate figure of rolling resistance and to better understand the variability of air temperature, materials, *etc.*. Another stakeholder also recommended including the effect of deflection, which would be covered by the direct measurement of the rolling resistance.

2.2.3 Final criteria proposal

Core criteria	Comprehensive criteria
AWARD CRITERIA	
	B13. Performance requirements on traffic fuel consumption due to rolling resistance *(Only for motorways and highways, main roads or national roads designed to bear high AADT[10] - Annual Average Daily traffic - at steady speed)* The contracting authority may choose one of the options below to implement this criterion. For all three options, it must be required that the MPD shall ensure the compliance with the skid resistance and wet friction required by national, regional and/or local legislation.
	Option 1 Points will be awarded to those offers that commit to a lower **MPD** of the road surface, within the range of safety conditions set by the skid resistance and the wet friction.
	Option 2 Points will be awarded to those offers that commit to a lower **rolling resistance** of the road surface. This option should only be used if the following three requirements are met: 1. the contracting authority sets the test method to be used for the direct measurement of rolling resistance in the ITT, and; 2. the tenderers have access to laboratories that test the rolling resistance according to that test method, and; 3. the test method is validated according to the provisions of ISO 17025.
	Option 3 Points will be awarded to those offers that commit to a road surface which will reduce **traffic fuel consumption.** The contracting authority will provide the tenderers with the tool including the planning data (route, traffic flow, average degree of curvature, rise and fall/gradient). The tenderer shall include the design parameters influencing the fuel consumption declaring those values together with their levels of uncertainty, and the level of uncertainty of the traffic fuel consumption estimation.

10 High AADT may vary across EU countries and regions, therefore the range regarded as 'high' should be evaluated by each Road Authority. As a general rule of thumb, literature indicates that the threshold between high and low traffic volume is around 2000-3000 AADT.

	Verification: **<u>All options:</u>** The design team, DB tenderer or DBO tenderer shall provide the detailed design including the performance parameters declared together with test results on a representative test sample of the surface. Tests shall be carried out by an independent laboratory complying with the general principles of ISO 17025. **<u>Option 1:</u>** the MPD shall be measured according to the standard ISO 13473-1. **<u>Option 2:</u>** the rolling resistance shall be measured by means of the test method set by the contracting authority in the ITT. **<u>Option 3:</u>** The design team, DB tenderer or DBO tenderer shall provide the results of the expected fuel consumption by means of the MIRAVEC tool or, where existing, other equivalent assessment tools. To be regarded equivalent, those tools shall include the following parameters: - Fuel consumption model for free flow traffic based on: o Vehicle characteristics (type, fuel used, Euro class); o Rolling resistance, air resistance, average degree of curvature, rise and fall/gradient, velocity; - Rolling resistance dependent on ambient temperature, IRI, MPD; - Vehicle velocity, based on posted speed, vehicle type, traffic volume, gradient, IRI and rutting present; - Idle time.
CONTRACT PERFORMANCE CLAUSES	
	C2. Quality of the completed road - monitoring of the performance parameters The main construction contractor *or* the DB contractor *or* DBO contractor shall monitor the agreed rolling resistance performance parameters affecting the traffic fuel consumption after the construction before the road opening and 6 months after the opening (in-service road), and provide a copy of test results. In case of non-compliant results, refer to general contract performance clause text in C1.

<u>Summary rationale for the final criteria proposal:</u>

- Traffic during the use phase dominates the life cycle impacts of a road with expected high traffic volume. Studies in the literature indicate that a 10% reduction in the rolling resistance can lead to 1-2% improvement in fuel economy.
- Rolling resistance is a function of many performance parameters, mainly macrotexture, unevenness and stiffness. The relation of fuel consumption and the change of MPD and IRI was investigated, showing that MPD is the most influencing parameter to decrease fuel consumption.
- An improvement on MPD to decrease the rolling resistance of the road surface can conflict with safety conditions, particularly with skid resistance. Any criterion on MPD shall therefore be framed within the safety requirements for the road surface.

2.2.4 At what stage of the procurement process are the criteria relevant?

Evaluation of the traffic flow expected in the road shall be done in the preliminary scoping and feasibility phase. If it is high traffic flow, rolling resistance may be a relevant environmental issue. For low traffic roads and those with frequent stop-start traffic flows, a criterion to decrease the rolling resistance is not recommended.

Requirements for macrotexture of materials and their expected service life given shall be proposed in the detailed design. This information should be included in a Maintenance and Rehabilitation (M&R) Strategy Plan.

Verification of macrotexture of materials before road opening shall be done in the construction phase. Pavement performance related to of macrotexture shall be assessed, monitored and verified during the use phase.

Maintenance activities have to be realised according to the M&R strategy plan in the maintenance and operation phase, taking into account the target values of the MPD parameters in the detailed design (if replacing the overlay frequently or doing complete rehabilitation of the surface course).

The criteria classification, their reference numbers in the criteria document and the respective procurement phase can be cross-referenced as follows.

Title of the criterion	Procurement phase	Criterion classification	Criteria typology	Reference number in the criteria document
Performance requirements on traffic fuel consumption due to rolling resistance	B. Detailed design and performance requirements	Comprehensive	Award criterion	B13
Quality of the completed road - monitoring of the performance parameters	C. Construction	Comprehensive	Contract performance clause	C2

2.3 Resource efficient construction

2.3.1 Introduction on the holistic performance approach

According to the LCA literature for roads carried out in the preliminary report, the second largest source of environmental impacts after the use phase is the production and transportation of construction materials. In low traffic roads, this can in fact be the most significant source of environmental impacts. Also, the durability of road materials is a key factor that will influence the requirement for maintenance. The impacts of maintenance activities themselves are dominated by impacts from materials production/transport and also congestion as mentioned in the previous section.

According to the review, factors that influence the choice of materials include the uniqueness of the local conditions, geotechnical and hydro-geological conditions, common practices of the relevant road administrations, climate conditions, availability of natural resources and secondary resources including by-products, transportation distances, prices, and weather conditions. The same GPP criteria areas have been highlighted in the Australian greening road procurement (Lehtiranta *et al.*, 2012).

The embodied impacts[11] **of construction materials production** and their **transportation** are environmental hot spots in both the construction and the maintenance phase. The main environmental impacts identified in the majority of the investigated studies are: consumption of non-renewable resources, global warming, acidification, photochemical ozone formation and eutrophication.

The main materials used in road construction are:

Asphalt: A composite material consisting of aggregates, filler, bituminous binder and possible additives that are heated and mixed together before placement.

Concrete: A composite material consisting of aggregates, filler, cement and possible additives and admixtures that are mixed with water before placement. Reinforced concrete and concrete slabs also contain steel reinforcement bars and dowels. In **blended cements** a part of the Portland clinker is replaced with pozzolan materials, slag or limestone filler.

Aggregates: aggregates are granular material used in construction. With reference to EC JRC, 2009; Böhmer *et al.*, 2008; EC JRC, 2014; WRAP, 2014, they can be classified according to the source of materials as following:

- natural aggregate: aggregate from mineral sources which have been subjected to nothing more than mechanical processing (according to EN standard);
- recycled aggregates: aggregate resulting from the processing of inorganic material previously used in construction (according to EN standard);
- secondary aggregates: aggregates obtained from others (*e.g.*, industrial) processes that have not been previously used in construction (EC JRC, 2014). This category includes:
    - o manufactured aggregates (by-products and/or re-used/recycled/recovered) defined as aggregates of mineral origin resulting from an industrial process involving thermal or other modification (according to EN standard);
    - o natural secondary aggregates (such as china clay sand, according to WRAP, 2014) and extraction by-products of construction and civil engineering activities (EC JRC, 2009).

Aggregates are used in unbound (where aggregates are not bound) and bound (where the mixture contains binding agent, such as cement, bitumen or a substance that has binding properties, in contact with water, similar to cement) types of applications in the different road pavement courses (EC JRC, 2009). In Annex A of the EN13242: 2013 an inventory list for source materials has been proposed; however this standard has been withdrawn and a previous version (2007) without the above-mentioned list still applies.

11 *Embodied impacts are related to the production of construction materials and products, including the resources used to manufacture products and process materials as well as emissions arising from raw material extraction and energy used in their processing, also termed embodied energy*

Materials as concrete and asphalt have smaller embodied energy and environmental impacts than other construction materials. However, since they are used in very large quantities in the construction industry, they become responsible for a large share of the gross embodied energy in environmental impacts (Blankendaal *et al.*, 2014).

In the literature, it is highlighted that environmental savings can be reached with the following materials:

- **Warm mix asphalt (WMA), half warm mix asphalt (HWMA), cold mix asphalt (CMA)** in substitution of hot mix asphalt (HMA);
- **Re-used/recycled materials and by-products,** of which the most important ones appear to be:
    - **Reclaimed asphalt pavement (RAP)** in bound and unbound applications;
    - **SCM – supplementary cementitious materials,** such as silica fume, ground granulated blast furnace slag (BFS) and fly ash used to replace clinker in cement or cement in concrete mixes (concrete, mortar and grout applications);
    - **Recycled aggregates from C&DW,** used usually in unbound applications;
    - **Recycled concrete**, used in bound and unbound applications;
    - **Manufactured aggregates** such as for example iron and steel slag, coal combustion ashes, municipal Solid Waste Incinerator (MSWI) bottom ash, reclaimed rubber from tyres (EC, JRC, 2009; WRAP, 2014), used in bound and unbound applications;
    - **Excavated materials and soils**, re-used preferably in close loop inside the same worksite (EC, JRC, 2009; WRAP, 2014).

A study published by the BAM group, a construction firm operating mainly in North-Western Europe, presented several scenarios for the main materials used in road construction, *i.e.*, asphalt and concrete, evaluating their environmental performances by means of an LCA (Blankendaal *et al.*, 2014). Specifically, it quantified the effect of low-energy production techniques and the use of recycled materials by applying the ReCiPe endpoints assessment, which consists in a damage-oriented method that considers damage to human health, ecosystem quality and depletion of resources. Impacts of concrete and asphalt from a cradle to grave perspective and the use of recycled concrete in concrete production and of RAP in asphalt production have been analysed. The evaluated concrete-mixes (typical Swiss mix) point out that the highest potential for improvement can be realized through application of alternative cement types. The scenarios show a maximum reduction of 39% in environmental impact (Figure 13). The most substantial impact reduction in asphalt can be realized through application of WMA instead of HMA. This yields a reduction of about 33%. Currently about 40% RAP is on average used in asphalt production. A further increase of 20% RAP application yields about 12% in environmental impact (Figure 14).

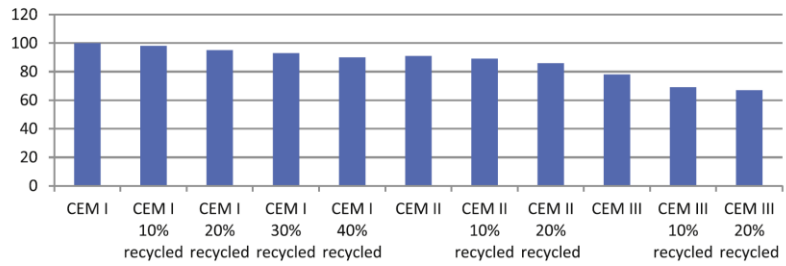


Figure 13: Example of normalized environmental impact of concrete (Blankendaal *et al.*, 2014).

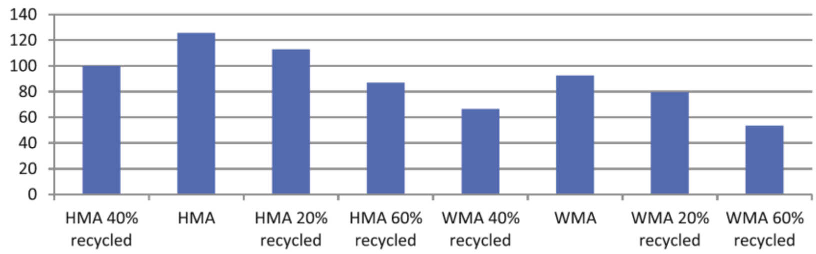


Figure 14: Example of normalized environmental impact of asphalt (Blankendaal *et al.*, 2014).

The potential environmental savings mentioned above have also been identified in the study "Assessment of Scenarios and Options towards a Resource Efficient Europe" (EC, 2014). The latter suggests 10 improvement options regarding resource efficiency for residential buildings, commercial buildings and roads, evaluated by means of an LCA approach (the complete LCA is reported in PE, EC, 2013). The study applied the combination of a bottom up approach (LCA and LCC per each technical improvement option) and a top-down approach (first a EE IO analysis and then the EXIOMOD model). The main resource efficiency improvement options for roads in Europe by 2030 are defined by means of the LCA/LCC in combination with the EE IO and are listed in Table 7.

Table 7: Assessment of Scenarios and Options for roads (EC, 2014)

Options	Options for road	Potential accompanying policies
3: Increase recycling of waste at the EoL	3.1) Recycling of RAP; 3.2) Re-use concrete and excavated soil.	More stringent requirements to realise 70% recycling of C&DW required by WFD. Ecolabel and GPP criteria including recycled content.
5: Increase use of recycled materials	5.1 Use of recycled aggregates from C&DW in road base and building fill; 5.2) Use of stockpiled fly ash to replace fly ash to replace cement in concrete applications or as grout/aggregate.	Ecolabel and GPP criteria, including demands for recycled content. In due time: minimum standards via e.g. the Ecodesign directive. R&D support for landfill mining.
9: Selection of materials with lower impact	9.3) Use of WMA in substitution of HMA.	Ecolabel and GPP criteria.
2: Increase durability and service life of products	*2.3) CMA* This option is not considered as prominent in the above-mentioned report.	

The study did not consider CMA as an option but, according to stakeholders' feedback, CMA and HWMA have been further developed with promising results and could potentially be used in different construction layers and even as surface layer on (very) low traffic volume roads.

Holistic performance approach

In the first draft of the technical report (February 2014), separated criteria areas for the most relevant materials, such as asphalt, concrete and cement, aggregates (natural, recycled and secondary) and soils, including lime and other stabilizers, have been proposed. It was underlined that the public authority during the planning phase can suggest and define a list of the most important materials to undergo an assessment/evaluation and indicate them in the ITT. Therefore, the proposed criteria were not envisaged to oblige contractors to only use certain materials but instead to provide a logical framework which encourages the use of materials with lower environmental impacts (according to the literature review and to EC, 2014) where possible and practical, including their transportation. As conclusion of this logical framework, it was also proposed to identify resource efficient materials by means of a more comprehensive LCA analysis.

Stakeholders expressed their concern that detailed criteria set separately for different materials may not stimulate sustainable solutions adding that the adoption of an holistic performance based approach in order to allow the design team, the DB tenderer or the DBO tenderer to propose more innovative and sustainable solutions is preferable. Open procurement processes based on road performance where tenderers can develop their own solution satisfying performance requirements should be established.

Stakeholders suggested that having detailed criteria on different construction materials is not the correct approach in infrastructure, considering that every project is unique and thus flexible criteria are needed. They suggested procuring by means of a process that considers all phases of the project, calculating the environmental performance for the whole construction by means of a LCC/LCA approach and new contracts as, *e.g.*, PPP.

Stakeholders suggested that GPP guidelines should strongly encourage NRAs and regional/local authorities to compare alternative types of pavement structure and materials in order to maximize economic, societal and environmental performance of the road infrastructure over its entire life cycle. It has been suggested to include the environmental criteria as much as possible within the LCA. Stakeholders highlighted that for MSs in which an LCA approach is still not a consolidated option, this proposal might boost improvement. However, criteria to be applied in case that the LCA is not required are also proposed. In Section 2.3.2 a LCA performance approach has been proposed taking into account boundaries definitions and rules for allowing comparability between LCA results.

However, a criterion is also proposed for the case that procurers decide not to award points by means of the Carbon footprint (CF) /LCA criterion (see section 2.3.2). This regards the CO_2e emissions from materials transportation (see section 2.3.4). It could be applied for example in case of projects under a certain economic value or for limited maintenance activities.

With reference to the recycled content in materials, most stakeholders supported the proposal of encouraging the use of recycled materials and by-products, but not for each material because of the need to apply the above mentioned holistic approach. Stakeholders suggested a non-prescriptive approach regarding material that would allow the design team, the DB tenderer or the DBO tenderer to comply with (or exceed for the award criterion) the recycled content requirements according to the availability of the materials on the local market. Recycled materials are well regulated as regards their performance requirements. According to this suggestion, a single recycled content criterion for the total weight of all construction materials is proposed. (section 2.3.3) to be used as an alternative to the CF/LCA approach.

2.3.2 Life cycle performance requirements of the main road elements

2.3.2.1 Background technical aspects, discussion and rationale for life cycle performance requirements of the main road elements

In the following paragraph a Carbon Footprint (CF) and a Life Cycle Assessment (LCA) performance approach is developed, according to ISO 14067, 14040 and 14044. The environmental performance of a construction material depends generally on its use within the road. Therefore, the entire life cycle of a road has to be assessed to determine the environmental contribution of construction materials (such as asphalt, concrete) and road elements (such as sub-base, base and surface courses). Materials have to be compared on the basis of a common functional unit, *i.e.*, considering aspects such as technical performance, durability, recyclability, *etc.*. Transport and need for maintenance over the pavement service life should also be included. According to the literature review, the pavement-vehicle interaction during the use phase should also be taken into consideration. For example a higher embodied energy or less durable road surface could be justified if it presents a lower rolling resistance and thus lower fuel consumption for vehicles. The relative importance of this will depend greatly on the traffic flow and whether or not the road is designed to be freely flowing or not.

Characterising the different systems used by existing schemes for road and civil works

Well-recognised labels that identify lower environmental impacts of infrastructures as a whole and/or of construction materials and products exist and are classified according to ISO 14024 as Type I Ecolabels. These generally take into account the environmental impacts along the entire life cycle. However, the most important construction materials and products are not covered by these ecolabels. Some ecolabels address life cycle impacts at the level of the whole building, and may include mandatory or optional criteria to carry out an LCA for the whole building. In case of infrastructures, a similar system is currently under development.

Environmental Product Declarations (EPDs), developed according to ISO 14025 and ISO 21930, are Type III labels that can provide environmental information from LCA studies in a comparable format, based on common rules, known as Product Category Rules (PCRs). EPDs do not prove that a product or material is environmentally friendlier but, generally speaking, the manufacturers make declarations in order to communicate better performance which is usually externally verified by a third party. The use of EPDs could make possible a comparison of the environmental impact at the level of technically equivalent construction materials or at the level of road elements or even a whole road when assessing the environmental performance of an infrastructure. To be comparable, EPDs must have the same PCRs, to ensure that scope, methodology, data quality and environmental impact indicators are the same and that all the relevant life cycle stages have been included within the study.

With the advent of the European single market for construction products, there was a concern that national EPD schemes and the assessment schemes at building and civil work engineering level would represent a barrier to trade across Europe. CEN TC 350 has been mandated to develop voluntary horizontal standardized methods for the assessment of the sustainability aspects of new and existing construction works and standards for the EPD of construction products. The European standardisation approach mandate is based on a lifecycle assessment methodology covering production (mandatory), construction, use (including maintenance) and end of life stages (all optional). Two standards have been developed and published by CEN TC350:

- EN 15804: 2012+A1:2013. This standard provides the PCRs for all construction products and services, with the aim to ensure that all EPDs of construction products, construction services and construction processes are derived, verified and presented in a harmonised way. 4 modules are included: A. Product + Construction; B. use stage; C End of life – D benefits and loads beyond the system boundary;

- EN 15978: 2011. This standard deals with aggregation of the information at the building level, among other describing the rules for applying EPDs in a building assessment. The identification of boundary conditions and the setting up of scenarios are major parts of the standard.

These published standards refer to building and construction products used in building. Standards on civil engineering works are currently under development by CEN TC 350 WG6. Cradle to gate EPDs (modules A1-A3) might probably follow the same rules as issued according to EN 15804. Cradle to grave EPDs will probably need the development of specifics PCRs or Annexes to the EN 15804 to better target sub-module B to civil works. The development of the framework on the assessment of sustainable performance of civil engineering works started in middle 2014 and will finish in middle 2016, while the standard on the calculation methods for civil engineering works will be probably published in middle 2017, according to the knowledge of the authors.

At international level, ISO 21930 assess the EPDs of building products based on ISO 14025. ISO/DTS 21929 is developing indicators for environmental assessment of civil engineering works.

EPDs schemes

Many European countries, including France, Germany, the Netherlands, the Nordic countries and the UK, have developed national PCR schemes regulating the use of EPDs (see Annex 2 Figure A2).

The main national EPDs schemes have been, or are in the process of being, aligned with EN 15804, such as for example in BRE 2013. These schemes refer to building products and their scope is cradle to grave (BRE and FDES) or cradle to gate plus optional information on transport and EoL (IBU EPD and Environdec) (CPA, 2012).

A similar system is not available in the case of civil engineering works, also considering that the standards are currently under development. There is only a PCR developed for highways, streets and roads (Environdec, 2013). This PCR refers to ISO 14040-14025, but indicates EN 15804 and ISO 21930 as underlying standards. According to it, one EPD on a road infrastructure has been published in 2014 (Acciona, 2014). Considered life cycle stages are construction, operation and maintenance, while the use phase is excluded, as shown in Figure 15. Declared unit is defined as 1 km of road and year.

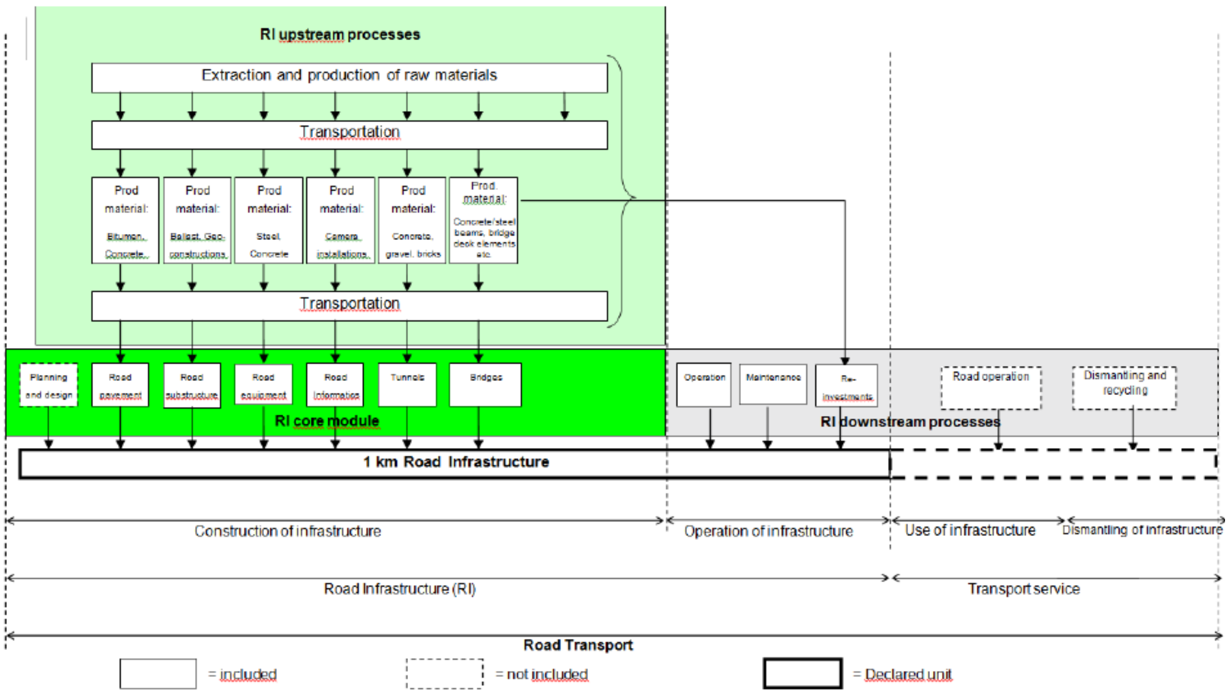


Figure 15: Flowchart of the product system for road infrastructure (Environdec, 2013).

Moreover, during the 2nd AHWG and the 2nd round consultation, stakeholders highlighted that specifications for civil works might be included in the same EN 15804, which therefore may be used in the near future as a reference standard also for infrastructure. For this reason, when EPD data is referred to, it seems to be reasonable to make a reference to EN 15804 in addition to ISO 14025, according to the stakeholders' feedback.

Environmental performance assessment schemes and tools for civil works

The development of methods for assessing the environmental performance of buildings are well structured in EU, while are evolving in case of civil works, including roads. Several LCA software programs can be used to assess the impact of buildings as a whole and for the selection of construction materials used in buildings. In detail, the most used certification for building schemes across EU uses a range of different approaches to the use of EPDs or LCA-based construction material, product and/or element assessments (EURIMA, FORCE, 2012). The following have been identified and are briefly described:

- BREEAM refers to the *Green Guide to Specification* as the basis for scoring the embodied impacts of construction materials (A+ to E rating system). The *Green Guide* is an EPD system for generic and certified construction materials and building elements from a cradle-to-grave perspective level (ISO 14040 and EN 15804);
- GPR Building (NL) applies a harmonised LCA approach for material impacts. Key performance indicators are aggregated into one index, called the "environmental shadow costs" of a building;
- DGNB (DE) uses a building level LCA to evaluate building and construction materials (EN 15804 and EN 15978). Normalization and weighting factors are applied to the impact categories;
- HQE (FR) allows the assessment of several impact categories for construction materials according to EN 15804 and EN 15978.

For civil works, there are some existing green road rating systems, as Invest (Australia), Greenroads (USA) and CEEQUAL (UK) (see Table 8). According to stakeholders, these systems could be more attractive to contractors in terms of marketing. In these road schemes, assessment of construction materials and products and their embodied energy is not based on an LCA approach. They consist in multi-criteria rating systems that provide points to different assessment categories (for example Greenroads gives points if an LCA is provided, but not to the LCA results).

Other assessment methods are under development, as BREEAM-NL for infrastructure and the LCE4ROADS FP7 project methodology[12]. The main objective of the latter project is *to develop a new, green, holistic and EU-harmonised certification methodology for roads integrating by a Life Cycle Engineering (LCE) approach the following aspects: environmental, economic, social and technical*.

The Sustainable infrastructure approach (Duurzaam GWW, 2011) developed within a joint initiative between different Dutch authorities (RWS among them) incorporates sustainability in infrastructure projects as following:

- in the concept phase, opportunities and ambitions are defined;
- in the design phase, the entire life cycle is analysed (construction, utilisation, asset management, maintenance and EoL) trying to apply a cradle to cradle approach and considering the Total Cost of Ownership (TCO). The tool CO_2 Performance Ladder is used to achieve CO_2 reductions and energy savings. Quantitative sustainability requirements are assessed by means of an LCA using the DuboCalc tool, more focused on environmental performance (not only CO_2) of materials. The choices made are justified and provided with motivation in a *sustainability transfer-document*, including Dubocalc calculation or test results. The information in this document can be checked against the design results and thus verified against the original ambition levels (*i.e.*, the specific *Ambition Web*). It is also suggested that when the Design contract is separate from the Build contract, the conclusion of the Design contract is associated with the delivery of a sustainability transfer document. Moreover, it is underlined that in integrated contracts (DB and DBO), a stipulation should be included that the contractor prepares a *sustainability transfer document* before starting the

12LCE4ROADS. Life Cycle Engineering approach to develop a novel EU-harmonized sustainability certification system for cost-effective, safer and greener road infrastructures. http://ecolabelproject.eu/

construction phase and contribute to clustering the relevant sustainability documents during the project;

- In the construction phase, the *sustainability transfer document* for the construction phase sets out how the sustainability requirements have been met. Doing so is (largely) the responsibility of the contractor. The *transfer document* should preferably contain an explanatory note on sustainability in the Maintenance and Management phase. These are (potential) requirements and guidelines for (continuing to) achieve the sustainability ambitions pursued. These also include the required specifications and measures for sustainable demolition.

In the EU, several LCA tools have been developed to assess the impact of roads and for the selection of construction materials (see Table 9). For example, the abovementioned Dubocalc tool which contains a detailed inventory of Dutch data, Aspect (asphalt pavement embodied carbon tool) and Aggregain based on UK data, CHANGER of the IRF, SEVE (used in France), ROAD-RES in the Scandinavian countries (see Table 9). These tools use specific national database (as the Dutch SBK nationale mileudatabase, the French Inies and the UK) or commercial LCA databases (such as GaBi or Ecoinvent). These tools are country-specific and could be used in other countries by means of adaptation of the LCI.

It has to be highlighted that, nowadays, the lack of widely available high quality databases at European level is one of the main obstacles to be solved to have a harmonised and representative system. Stakeholders stressed the importance of developing databases for assessing the environmental performance of construction materials in the EU. This would be beneficial for both the building and the civil infrastructure sectors.

Other tools have been developed within EU research projects, as CEREAL (CO_2 Emission Reduction in roAd Lifecycles) joulesave, LICCER and MIRAVEC (Table 10).

It can be concluded that:

- Standards on civil engineering works are currently under development. There are EPDs (mostly cradle to gate) for construction materials used in road construction and one PCR on road infrastructure. Aggregation of EPDs results as in the BRE Green Guide to Specification in which EPDs of building elements are aggregated from a cradle-to-grave perspective is not yet available;
- Most of the analysed evaluation methods and related tools are on the carbon footprint (aspect, Changer, CO_2 ladder, Klimatkalkyl, CEREAL, LICCER). Considered life cycle phases are usually construction (including materials production and transportation) and maintenance (including operation). In few methods only the construction phase is considered. Some tools are oriented to assess only specific materials or road elements (as Aspect and Aggregain). Some of them have been developed for the planning phase (EIA, SEA), as LICCER and MIRAVEC;
- There are some more advanced evaluation methods and related tools in which the environmental performances of road construction materials are assessed (such as Dubocalc, Road-Res). They are based on ISO 14040-14044 and evaluate several impact assessment categories. In Dubocalc, they are converted into one index (Environmental Cost Indicator MKI) called the shadow price, which is expressed in euro per km of road per year of impact assuming a 50-year lifespan. Weighting systems are not applied;
- Use phase, specifically the interaction between vehicle and pavement is not yet included in these methods and tools. Therefore they do not include consideration on the fuel consumption related to the final surface texture / rolling resistance. According to the literature review, this is the main hot spot, at least for high traffic roads;
- New tools developed in the framework of some EU projects started including some consideration on traffic (AADT) in the use phase, even though are more oriented to the planning phase (LICCER, MIRAVEC). The latter use is only focused on the use phase. These tools can be used, in a first stage, to evaluate impacts in the use phase and in particular the fuel consumption.

Stakeholders commented that even though the pavement-vehicle interaction is relevant, it is premature to include it within the LCA because of the lack of available data and of commonly available, validated, accepted and spread model(s)/calculation tool(s) for evaluation of vehicle fuel consumption. In Belgium, a first limited pilot project is ongoing with respect to take into account energy consumption and traffic, but a stakeholder underlined that it is premature to draw any conclusions.

Table 8: Comparison of main assessment methods.

Scheme	CEEQUAL	Greenroads	Invest	LCE4ROADS
Assessment method	ICE (UK and Ireland) version 5 (2012)	University of Washington (UW) and CH2M (USA)	Vicroads (Australia)	LCE4ROADS consortium FP7 –SST 2013.5-3. Team leader ACCIONA (ES)
Sustainability rating system and assessment categories (weight level)	Sustainability rating system [25% pass, 40% good, 60% very good, >75% excellent] - Project/Contract Strategy (optional) - Project Management (10.9 %) - People & Communities - Land Use (above & below water) (7.9 %) and Landscape (7.4 %) - Historic Environment (6.7 %) - Ecology & Biodiversity (8.8 %) - Water Environment (Fresh & Marine) (8.5 %) - Energy and Carbon (9.5 %) - Physical Resources Use (9.4%) & Management (8.4 %) - Transport (8.1 %) - Effects on Neighbours (7%) - Relations with the Local Community and other Stakeholders (7.4 %)	Sustainability rating system [certified 32-42/108, Silver 43-53/108, Gold 54-63/108, Evergreen>63/108] - Environment and water - Access and equity - Construction activities - Materials and resources - Pavement technologies - Custom credit	Sustainability rating system [1 star +60, 2 stars +90, 3 stars +130, 4 stars +180, 5 stars +240] - Air quality - Behavioural change & capacity building - Biodiversity - Cultural heritage - Community engagement - Energy management - Noise management - Resource management - Urban design - Water management	Sustainability sets of requirements to be accomplished. Two levels (light and complete) and four domains covered. - Environmental - Social - Technical (including climate change related extreme events - Economic *Under development*
Environmental indicators	- Climate change - Materials and resource use - Waste - Transport - Water pollution - Land use - Biodiversity	- Fossil fuel reduction - Emission reduction - Water use - Recycled materials - Waste management - Durability - Permeable pavements - Use of WMA - Quiet pavements		- Acidification - Eutrophication - Global Warming - Primary Energy Demand - Photochemical Ozone Creation Potential
Weighting	Yes	Yes	Yes	Yes
Certification	Certified by an assessor	-	-	Yes

Table 9: Comparison of main tools available for road construction and materials.

Scheme	asPECT[13]	Aggregain	Changer	CO_2ladder	Dubocalc[14]	ROAD-RES[15]	Klimatkalkyl[16]	Seve
Assessment method	HA, MPA, RBA and TRL (UK)	TRL and funded by WRAP (UK)	IRF	Rijkwaterstaat (NL)	Rijkwaterstaat (NL)	DTU (DK)	STA (SE)	Usirf (FR)
Life cycle phases	Construction Maintenance End of life (flexible pavem.)	Aggregates used in construction	Construction	Construction Maintenance and operation End of life	Construction Maintenance and operation End of life	Construction Maintenance and operation End of life	Construction Maintenance	Construction Maintenance End of life
Ref. standard	ISO 14044 IPCC2007	ISO 14040	IPCC2007	ISO 14040	ISO 14040	ISO 14040	IPCC2007	
Impact assessment categories	Global warming (GWP)	Global warming (GWP) Eutrophication (EP) Acidification (AP) Photochemical oxidant creation potential (POCP) Human Toxicity Potential (HTP) Freshwater Aquatic Ecotoxicity (FAETP) Ecotoxicity sediments Terrestric Ecotoxicity Potential (TETP) Ozone Depletion potential (ODP)	Global warming (GWP)	Global warming (GWP)	Global warming (GWP) Abiotic depletion potential (ADP) Ozone Depletion potential (ODP) Photochemical oxidant creation potential (POCP) Human Toxicity Potential (HTP) Freshwater Aquatic Ecotoxicity (FAETP) Ecotoxicity sediments Terrestric Ecotoxicity Potential (TETP) Acidification Potential (AP) Over fertilization Depletion of renewable materials	Global Warming (GW) PhotoChemical Ozone Formation (POF) Nutrient enrichment (NE) Acidification (AF) Human toxicity air (Hta) Human toxicity water (HTw) Human toxicity soil (HTs) Ecotoxicity water (Etw) Ecotoxicity soil (Ets) After 100 years Stored Ecotoxicity water (SETw) Stored Ecotoxicity soil (SETs)	Global warming (GWP) Energy consumption (MJ)	Global warming (GWP) Energy consumption (MJ process) Use of resources - RAP (t) - aggregates (t) Transportation (t*km)

Table 10: Comparison of main tools in EU projects.

Scheme	**CEREAL** *ERA Net II program*	Joulesave/ECRPD	**LICCER** *ERA Net program*	**MIRAVEC** *ERA Net program*
Assessment method	DHV (NL), KOAC-NPC (NL), DRD (DK)	Waterford County Council (IE) and other partners from CZ, FI, FR, PT, SE and UK	KTH, NTNU, Birgisdottir, Wageningen University, Ecoloop	AIT, TRL, VTI, ZAG, CDV, FEHRL
Reference standard	ISO 14040-14064, EN 15804, CESSM3 Carbon	ISO 14040	ISO 14040	
Life cycle phases	Construction Maintenance and operation *Applicable in all Europe*	Construction Use (traffic) Maintenance and operation	Construction Use (traffic) Maintenance End of life	Use (Fuel consumption model for free flow traffic)
Impact assessment categories	Global warming (GWP)	Cumulative energy consumption (CED)	Global warming (GWP) Cumulative energy demand (CED)	CO_2 emissions

13 http://www.sustainabilityofhighways.org.uk/NewsArticle.aspx

14 http://www.rws.nl/en/help/zoeken.aspx?query=dubocalc&zoek=Search

15 http://www.vegvesen.no/_attachment/110628/binary/192907?fast_title=Presentation%3A+Life+Cycle+Assessment+of+Recycling+Residues+from+Waste+Incineration+in+Road+Construction+in+Denmark

16 http://www.trafikverket.se/klimatkalkyl/

Proposing different methodologies for assessing the environmental performance of a road

In order to evaluate the resource efficiency of different road designs there needs to be comparability both in terms of the Bill of Quantities (also sometimes referred to as Bill of Materials), functional requirements and the methodology used. In some cases a Bill of Quantities (BoQ) for a reference road or a preliminary design is provided to bidders within the ITT. In other cases, where designs are submitted by different bidders in response to a design specification (*e.g.*, in the case of DB contracts), the performance of these designs could be compared during a competitive process in order to encourage innovative resource efficient designs.

The BoQ for a reference road contains the preliminary evaluation of the amount and cost of main construction materials and road elements. The BoQ is put together on the basis of the preliminary information included in the concept and detailed design and aims to provide a common basis for bidders to put together their proposals and costing. This information could be used by tenderers to prepare their technical and environmental proposal, including a Carbon Footprint (CF) or an LCA analysis. Indeed, when the BoQ is provided, it should be possible to make a comparative evaluation of improvements in the life cycle performance of the main road elements.

In order to allow for flexibility in what is still an emerging area of expertise, with on-going process of standardisation, we have identified two options which could form the basis for ITT's as award criteria:

- Option 1: Carbon Footprint (CF) (as Core criterion);
- Option 2: Life Cycle Assessment (LCA) (as Comprehensive criterion) according to the following methods:

  2.1 Impact Category results: The aggregated characterisation results for each indicator obtained using the specified LCA method, representing a standalone LCA study;

  2.2 LCA tool score: A single score obtained using a national or regional LCA tool used by public authorities. This method is employed for example by Dubocalc.

Given that comparability is essential at procurement stage, a set of simplified guidelines have been developed with reference to ISO 14067 or equivalents and ISO 14040/14044.. These are intended to be used to establish the rules for design teams so that evaluations carried out according to options 1 or 2 are comparable. A further step is added to ensure that evaluations by design teams are robust by proposing that an LCA technical evaluator should support the procurer.

These guidelines are provided in Annexes A, B and C of the criteria document[17], and are proposed to be provided together with the GPP criteria document and provide specific information on comparability, technical guidelines and expert evaluation. A brief description and rationale is provided as following.

Comparability and uncertainty

Transparency of the results is very important for any analysis using CF or LCA. The sources of background data must be made clear, including how it was obtained or compiled, what kind of process and technology it represents, what is included in the data as well as possible sources of uncertainty (Dolezal *et al.*, 2013).

Every CF or LCA study shall provide:

1. A qualitative assessment of the uncertainties based on the information listed above, together with;
2. A quantitative assessment for the two most significant road elements identified from the analysis (see Tables a and b in criterion B14.).

Current standards deal with uncertainties in similar ways. The EU ILCD handbook and ISO 14044 recommend a completeness check, a sensitivity check to test the accuracy and precision of results and a consistency check. ISO 14044 emphasises the importance of choosing evaluation techniques that are consistent with the goal and purpose of the report.

In order to ensure comparability, the following rules shall be set:

- Option 1: Carbon Footprint (CF) (as Core criterion)

  In the CF option, CO_2e emissions are evaluated and compared, using the global warming potential (GWP) category indicator. This should have to be specified in the ITT. The selection of Life Cycle

17 Annexes A, B and C have been fully reported at the end of the Criteria proposal document

Inventory (LCI) data shall follow the quality requirements set out in ISO 14067. Verified primary data and supplementary secondary data may be used to fill gaps in the LCI following the guidance in ISO 14067 or equivalents, ISO 14025 and EN 15804 (if EPD data is used) but the selection and handling of this data, and the assumptions made, would need to be checked by the technical evaluator. ISO 21930 could also be used as underlying standards, if relevant.

- Option 2: Life Cycle Assessment (LCA) (as a Comprehensive criterion)

  The same LCIA method and Category indicators should be used in the LCA and would have to be specified in the ITT. The selection of Life Cycle Inventory (LCI) data shall follow the quality requirements set out in ISO 14040/14044 and, in addition, the ones set in EN 15804, section 6.3.7. Verified primary data and supplementary secondary data may be used to fill gaps in the LCI following the guidance in ISO 14040/14044, ISO 14025 and EN 15804 (if EPD data is used) but the selection and handling of this data, and the assumptions made, would need to be checked by the technical evaluator. ISO 21930 could also be used as underlying standards, if relevant.

According to the stakeholders' feedback collected during the 2nd round consultation, a reference to EN 15804, where EPD data is referred to, has been made.

Defining the road life cycle, boundaries, main road elements and functional unit

The most significant road elements have been identified according to the outcomes of the technical analysis in the preliminary report. The main hot spots in **construction** and **maintenance** are related to the **production** and **transportation** of the main materials used in road infrastructure such as cement production and concrete mix (including aggregates) and bitumen production and asphalt mix (including aggregates).

Materials **transportation** could account up to 50% of the energy consumption and emissions, depending on the local conditions. During construction and maintenance, materials transportation is an important parameter when natural aggregate is compared to recycled or secondary aggregates or by-products (Mroueh *et al.*, 2000; Olsson *et al.*, 2006; Blengini and Garbarino, 2010; Chowdhury *et al.*, 2010). According to the literature review, transportation distance of recycled and secondary aggregate can be 2-3 times greater than the transport distance of natural aggregates before the impacts of extra transport outweigh the avoided impacts in the recycling chain. However, transport of materials is unique to the specific road construction projects and can be optimized by using local materials as far as is practical. Moreover, the mass movement of excavated materials (soils, rocks) on-site should also be taken into consideration. In complex orography condition, the impacts related to **earthworks** and **ground works** can accounted for the main part of the total emissions and up to 30% of the project cost (Barandica *et al.*, 2013). From a GPP development perspective, the information in this section highlights the potential importance of planning a closed-loop re-use of excavated soils in or near the site in order to minimise environmental impacts. It should be considered that ICE Protocol (2008) indicates that 75% of the sub-soil could be re-used with normal practices, 85% with good practice and 100% with best practice. ENCODE (2013) propose 'diversion rates' of 50% for inert soil and stones that will be put to beneficial use (*e.g.*, backfilling and restoration). In the draft Italian GPP criteria for road construction and maintenance, it is proposed that at least 50% of excavated materials are re-used on-site.

Nowadays the maintenance phase plays a fundamental role, together with the construction phase, to identify strategies for sustainable infrastructures including evaluation on rolling resistance, congestion and materials durability. Operation phase (lighting, winter maintenance, etc.) is also included in the maintenance phase, even though according to the literature review the influence of this phase could be generally lower than construction and maintenance. Maintenance also includes the EoL phase of construction materials.

A stakeholder suggested including the light reflecting capacity of a pavement (albedo) and its influence on cost and energy of lighting within the LCA. According to Santero *et al.*, (2011b), limited published research is available on this topic, but it appears that material type, age, aggregate choice and other factors can influence the light reflectivity of a pavement and therefore the lighting requirements. The albedo-related environmental impacts (*i.e.*, urban heat island effect) have been analysed in some papers (Zaragoza and Bartolomè, 2012; EUPAVE, 2009; Akbary, 2009). These analyses have been performed considering a global scale and are not related to specific projects. Despite the potential savings in this field, it seems premature to draw conclusions that would allow the setting of GPP criteria.

Furthermore, it has to be considered that the impact of the lighting energy demand on the pavement life cycle will likely become smaller as more efficient lighting technologies (such as LEDs) are adopted. A specific link to the existing GPP criteria for street lighting and traffic signals, which are focused on efficient lighting technologies, is provided in section 2.6.1. Pavement LCAs should include lighting demand, but it is recommended that any calculation of lighting energy demand makes explicit the type of lighting technology that was assumed (according to Santero *et al.*, 2011b).

A stakeholder suggested also including the recarbonation effect, *i.e.*, the CO_2 re-absorption by concrete during its service life and particularly by crushed concrete in the EoL (EUPAVE, 2009). According to EUPAVE (2009), during concrete demolition the specific surface increases and the recarbonation reaction proceeds faster. A laboratory study shows higher carbonation rates for concrete mix design for buildings than mix design for pavements and the dependency to exposure level and humidity (Galan *et al.*, 2010). However, the WBCSD (2009) indicated that estimations and researches are still fairly nascent and, therefore, it appears premature to propose criteria in this field.

According to the outcome of the preliminary report, and to the examples provided in the LICCER project (Annex 2 Figure A3), the main road elements for flexible, rigid and semi-rigid pavements that should be at least taken into consideration both in <u>option 1: Carbon Footprint (CF)</u> and <u>option 2: LCA assessment</u> are:

- **sub-grade**, including earthworks and ground works (including barriers made by soil);
- **sub-base** (including road-base in case) with bound and unbound aggregates;
- **base** (bituminous bound in flexible pavements and hydraulically bound in semi-rigid pavements) and **binder and surface** (bituminous bound in flexible and semi-rigid pavements) *or;*

  concrete slabs (with an optional bituminous bound as surface in rigid pavement);
- additional **ancillary road elements** (such as concrete walls and barriers, drainage system, crash barriers, noise barriers, ITS, *etc.*) *(optional).*

The inclusion of additional ancillary road elements is optional because the main environmental impacts are not deriving from these elements, according to the LCA literature review performed and reported in the preliminary report. The contracting authority has to decide case by case if including the ancillary elements within the main road elements, based on the grade of completeness required in each CF or LCA study. For example, if different noise barriers materials have to be analysed, these road elements should be included in the LCA analysis.

All the identified main road elements have to be considered in a new road construction or major rehabilitation, including base course reconstruction, whilst only base, binder and surface courses or concrete slabs shall be taken into consideration in maintenance works. For the distinction between the different contract typologies in different road life cycle phase, please check Figure 1 in the *Procurement practice guidance document* (provided as a separate document).

According to the outcome highlighted in section 2.3.1, it is suggested to focus on the following materials which have the higher potential environmental savings:

- **WMA/HWMA/CMA** in substitution of HMA (see Annex 3);
- **Re-used/recycled materials and by-products** (see Annex 4), of which the most important appear to be**:**
  - **Reclaimed asphalt pavement (RAP);**
  - **SCM – supplementary cementitious materials;**
  - **Recycled aggregates from C&DW;**
  - **Recycled concrete;**
  - **Manufactured aggregates;**
  - **Excavated materials and soils.**

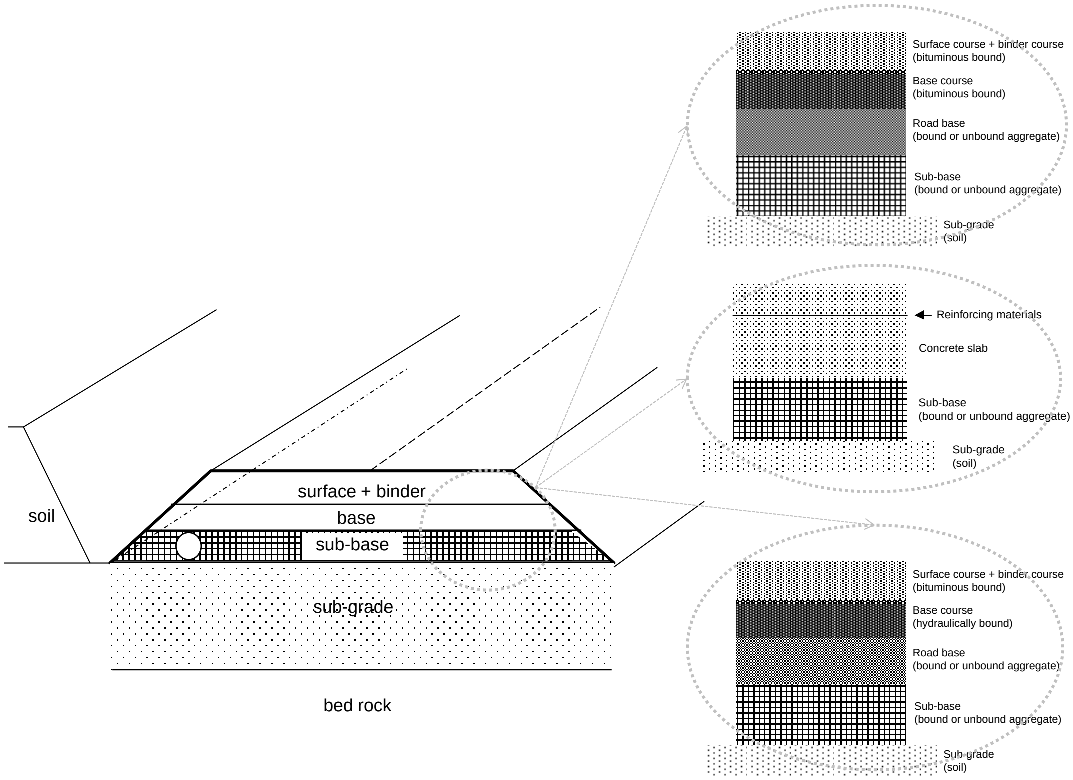


Figure 16: Identification of the main road elements.

As for the functional unit, this is suggested to be 1 km of road (or single lane) for the duration of its service life (usually 50 years).

In conclusion, the proposed road life cycle, boundaries and main road elements:

- Option 1: Carbon Footprint (CF) (as Core criterion)

  The boundary for the analysis shall be cradle-to-grave, including **construction** (including materials production and transportation) **maintenance and operation** and **EoL** (according to ISO 14067). Recycled or re-used materials either as inputs (product stage) or outputs (EoL or maintenance stages) have to be allocated according to the rules in ISO 14067 or equivalent and EN 15804. The main road elements identified in Figure 16 shall be at least included (all of them in case of separate Design and Built, DB and DBO contracts for the construction a new road or major rehabilitation, whilst only surface, binder and base courses in case of separate Design and Built, DB and DBO for maintenance activities). As a reference point for each design, the relevant technical and function requirements, the envisaged pattern of use and the requested service life should be the same for each LCA analysis and a common functional unit shall be used to present the results (according to ISO 14067).

- Option 2: Life Cycle Assessment (LCA) (as Comprehensive criterion)

  The boundary for the analysis shall be cradle-to-grave, including **construction** (including materials production and transportation) **maintenance and operation** and **EoL** (according to ISO 14040). Recycled or re-used materials either as inputs (product stage) or outputs (EoL or maintenance stages) have to be allocated according to the rules in ISO 14044 and EN 15804. The main road elements identified in Figure 16 shall be at least included (all of them in case of separate Design and Built, DB and DBO contracts for the construction a new road or major rehabilitation, whilst only surface, binder and base courses or concrete slabs in case of separate Design and Built, DB and DBO for maintenance activities). As a reference point for each design, the relevant technical and function requirements, the envisaged pattern of use and the requested service life should be the same for each LCA analysis and a common functional unit or reference unit shall be used to present the results (according to ISO 14040/14044 and to EN 15804, if relevant).

Following some stakeholders suggestion, the **use phase** (interaction between pavement and vehicle) has not been included in the boundaries of the study. However, a specific criterion on interaction between pavement and vehicle is proposed in this GPP criteria proposal. Moreover, the use of the MIRAVEC tool is suggested in order to define the fuel consumption related to the use phase.

During the 2nd round consultation, a stakeholder pointed out that there might be occasions where it would be preferable to specify a higher environmental performance as measure by the CF/LCA for the road construction if, over the whole life cycle, a great benefit can be derived from lowering the rolling resistance and therefore reducing the vehicle fuel consumption. Based on the feedback received from stakeholders, both CF/LCA options would need to be used in a way that recognised that there are relevant correlations with the use phase of the road. It is proposed to link the CF/LCA criterion with the criterion on traffic fuel consumption due to rolling resistance B13. option 3, in which it is proposed to evaluate the fuel consumption by means of the MIRAVEC tool or other equivalent assessment tools, where these are available (see scheme in Figure 17). Moreover, once CEN environmental assessment standards on civil works will be available and the assessment methods and tools more solid, it is suggested to include the pavement-vehicle interaction within the LCA.

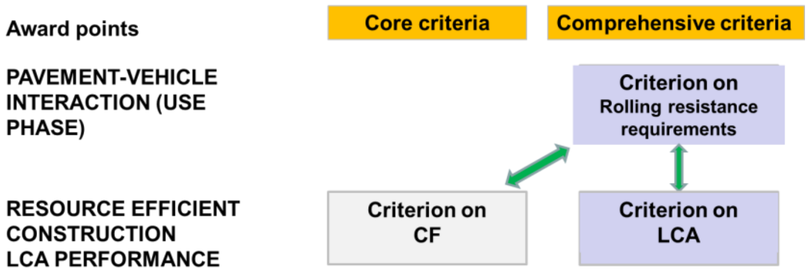


Figure 17: Scheme on the interrelation between CF/LCA criterion and the pavement-vehicle interaction criterion.

Defining the Life Cycle Impact Assessment (LCIA) Category indicators to be used

With reference to the reviewed LCA studies in the preliminary report and to Ortiz *et al.*, 2009, the main environmental impacts are consumption of non-renewable resources, global warming, acidification, photochemical ozone formation and eutrophication (see Table 11). Khasreen *et al.* (2009) specified that global warming potential is evaluated in almost every study, perhaps because GHG emissions can be more readily quantified than other impacts. Other impact categories such as toxicity, resource depletion potential, land use, water consumption and waste management are relevant impact but difficult to identify.

Table 11: Impact categories in the reviewed LCAs studies.

Impact assessment categories	Energy consumption	Global Warming	Acidification	Photochem. Ozone Creation	Eutrophication	Ozone Layer Depletion	Abiotic Depletion	Human Toxicity	Freshwater Aquatic Ecotoxicity	Marine Aquatic Ecotoxicity	Terrestric Ecotoxicity	Aquatic sediment ecotoxicity	Stored ecotoxicity water	Stored ecotoxicity soil	Land-use	Normalization	Weighting
Road infrastructure																	
SUSCON, 2006(a)	x	x	x	x	x	x	x	x	x	x	x						x
Santero and Horvath, 2009(a)	x	x															
Milachowski C. et al. 2011(a)	x	x	x	x	x	x											
Wang et al., 2012a(a)	x	x															
Wang et al., 2012b(a)	x	x															
Wayman et al., 2012 (a)	x	x	x	x	x	x	x	x	x	x	x					x	
Barandica et al. 2013(a)	x	x													x		
Loijos et al., 2013(a)	x	x															
Supply chain																	
Korre and Durucan, 2009(a)	x	x	x	x	x	x		x	x	x	x						
Blengini and Garbarino, 2010(b)	x	x		x	x	x		x	x	x	x	x			x		
Chowdhury et al., 2010(a)	x	x	x					x	x		x	x					
Birgisdóttir, 2005(c)	x	x	x					x	x	x	x	x	x	x			
Birgisdóttir et al., 2007(c)	x	x	x	x	x			x	x	x	x	x	x	x			

(a) LCIA according to CML2001 and GWP according to IPPC, 2007; (b) LCIA according to IMPACT2002+; (C) LCIA according to EDIP97

In Table 12 and Table 13 impact categories selected in the Environdec PCR for road (Environdec, 2013) and in the Assessment of scenarios and options toward a Resource Efficient Europe) of the EC under the flagship 2020 initiative (EC, 2014) and in EN 15804 are reported. Finally, similar impact category indicators have been selected by some tools for road (see Table 9).

Table 12: Impact category indicators according to the PCR on roads (ENVIRONDEC, 2013).

Impact assessment categories		**Unit**
Indicators describing resource use	Non-renewable resources: material resources / energy resources Renewable resources: material resources / energy resources Secondary resources: material resources / energy resources Recovered energy flows Water use	kg / MJ kg / MJ kg / MJ MJ L
Indicators describing environmental impacts	Global Warming Potential, GWP Acidification potential of soil and water; AP Eutrophication potential, EP Formation potential of tropospheric ozone photochemical oxidants, POCP	kg CO_2 equiv kg SO2- equiv kg (PO4)3- equiv kg Ethene equiv
Indicators on waste production	Hazardous waste (as defined by regional directives), Non-hazardous waste	kg kg
Additional information	Impacts on biodiversity - Noise and vibrations - Management of materials and substances - Water management	

Table 13: Impact category indicators considered in the Assessment of scenarios and options toward a Resource Efficient Europe (EC, 2014).

Impact assessment categories		**Unit**
Indicators describing materials	Abiotic Resource Depletion Potential for elements; ADP_elements	kg Sb equiv
Indicators describing energy	Abiotic Resource Depletion Potential of fossil fuels ADP_fossil fuels Primary Energy Demand Non Renewable PED-NR Primary Energy Demand Renewable PED-R	MJ, net calorific value MJ, net calorific value MJ, net calorific value
Indicators describing emissions	Acidification potential AP	kg SO2- equiv
	Eutrophication potential EP	kg (PO4)3- equiv
	Global warming potential GWP	kg CO_2 equiv
	Global warming potential excluding biogenic carbon GWP-EB	kg CO_2 equiv
	Ozone Depletion Potential ODP	kg CFC 11 equiv
	Photochemical Ozone Creation Potential POCP	kg Ethene equiv

Table 14: Impact category indicators to be included in the LCA considered in EN 15804.

Impact assessment categories		**Unit**
Indicators describing resource use	Use of renewable primary energy excluding energy resources used as raw material	MJ, net calorific value
	Use of renewable primary energy resources used as raw material	MJ, net calorific value
	Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials)	MJ, net calorific value
	Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials	MJ, net calorific value
	Use of non-renewable primary energy resources used as raw materials	MJ, net calorific value
	Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials)	MJ, net calorific value
	Use of secondary material	kg
	Use of renewable secondary fuels	MJ
	Use of non-renewable secondary fuels	MJ
	Net use of fresh water	m^3
Indicators describing environmental impacts	Global Warming Potential, GWP	kg CO_2 equiv
	Depletion potential of the stratospheric ozone layer, ODP;	kg CFC 11 equiv
	Acidification potential of soil and water; AP;	kg SO2- equiv
	Eutrophication potential, EP;	kg (PO4)3- equiv
	Formation potential of tropospheric ozone photochemical oxidants, POCP;	kg Ethene equiv
	Abiotic Resource Depletion Potential for elements; ADP_elements	kg Sb equiv
	Abiotic Resource Depletion Potential of fossil fuels ADP_fossil fuels	MJ, net calorific value

According to Scheuer *et al.* (2003), impact indicators such as global warming potential, ozone depletion potential, acidification potential, eutrophication potential and solid waste generation are close correlated with the primary energy demand. Other relevant impacts appear related to NOx and VOCs emissions that are quantified using indicators such as photochemical ozone creation potential (POCP).

An LCA model for the UK's built environment in a single year has been evaluated in the Assessment of scenarios and options toward a Resource Efficient Europe (EC, 2014) (unfortunately, a similar level of detail could not be found for Europe as a whole). Focusing on the impact categories of the main road construction materials (in Figure 18 classified such as aggregates, bituminous materials, concrete-cement & products, recycled-secondary materials) and according to the results of the technical and LCA review in the preliminary report, additionally to global warming, acidification, eutrophication, ozone depletion, it could be suggested that for road the main impacts are caused by the use of non-renewable and renewable resources, abiotic depletion resources, both for elements (related to the extraction of scares ores) and for energy/fossil fuels, and land use.

As previously introduced, the methodology to identify impact category indicators such as abiotic resource depletion potential or land use is under discussion in the scientific community. For example, EN 15804 states that indicators on toxicity and land use cannot be used due to the lack of scientifically agreed and robust calculation methods within the context of LCA and that the indicators describing the depletion of abiotic resources is subject to further scientific revision. In the criteria proposal for the 2nd AHWG it was suggested to consider as indicator the mass of non-renewable and secondary resources. However, many stakeholders commented that this is not an LCA indicator and that it could be more relevant to use Abiotic Depletion Potential (ADP) as it is based on availability/scarcity. Furthermore, they also highlighted that all the impact category indicators identified in EN 15804 should be used in the LCA option.

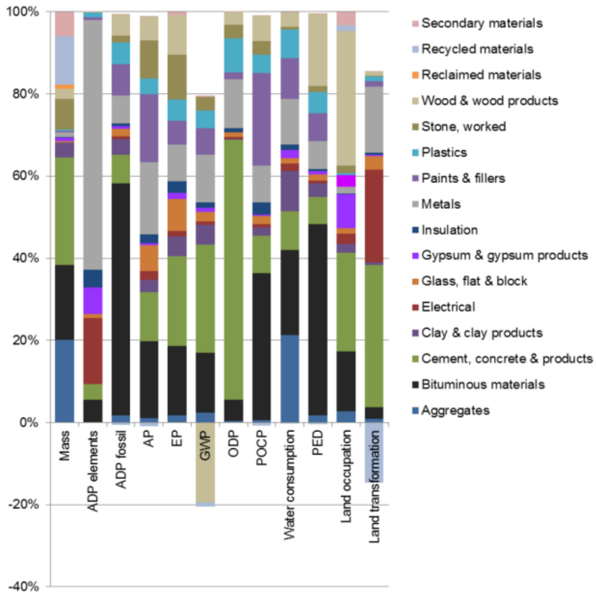


Figure 18: Environmental impacts associated with the consumption of construction products within the UK built environment (EC, 2014).

To sum up, according to the evidence of the above described LCA results and to the feedback received during the 2nd round consultation, in order to carrying out the impact assessment within the GPP criteria framework, it is proposed:

- Option 1 Carbon Footprint (CF)

  Bid designs will be compared on the basis of the global warming potential.

- Option 2 Life Cycle Assessment (LCA)

  The impact category indicators from the EN 15804 are listed below, and shall form the basis for a performance comparison when carrying out a LCA:

  - Global warming potential (GWP);
  - Depletion of abiotic resources-elements (ADP elements);
  - Depletion of abiotic resources-fossil fuels (ADP fossil fuels);
  - Formation potential of tropospheric ozone photochemical oxidants (POCP);
  - Depletion potential of the stratospheric ozone layer (ODP);

- Acidification potential of soil and water (AP);
- Eutrophication potential (EP).

With reference to the impact assessment models, it is suggested to refer to the characterisation factors applied in the EN 15804 Annex C and the LCIA models identified in the EN 15804 Annex C.8.

Whilst some stakeholders expressed disagreement with weightings because there is no consensus, others felt that a weighting should be defined in order to avoid inconsistencies in the comparison of bids. Given the need to be able to make a comparison between the performances of bids, a weighting system for the selected impact category indicators is, on balance, still considered to be important. It is therefore proposed that such a system shall be applied in order to evaluate the overall score.

There is no current weighting system defined for specific use of EN 15804 but various systems are in use within building assessment schemes and LCA methodologies, which might be used also for civil works in a close future. A weighting system proposed by JRC-IES for use in the development of resource efficiency indicators was reviewed as a potential basis for a recommended set of weightings (EC JRC, 2012c), but is based on the EU ILCD Handbook which adopts different methods and indicators. A weighting system developed by the US EPA as underlying reference used in the design of building assessment scheme SB Tool, but again this does not provide a clear weighting for the same impact categories (Mateus and Bragança, 2011).

Given the lack of an agreed weighting system at EU level, it is proposed that the choice of weighting system to be used by all bidders shall be made by the contracting authority on the basis of suitable existing weighting systems. These may include a weighting system adopted in a nationally available scheme or a weighting system proposed by the LCA technical evaluator (see Annex C). The technical evaluator is proposed to play a key role in helping the contracting authority to put together the LCA requirements to be included in the ITT.

The handover document

A *handover document* should be prepared at the end of the design phase and will sum up all the assumptions and results from the LCA. For example, this document could indicate the assumption on materials and CO_2e emissions per tonne of transported materials, providing a baseline mass haul plan that could be used as a base and optimized during following phases. This document could be used for preparing the following ITTs.

The need for expert evaluation of the design assessments

The lack of experience in the interpretation of the results of the studies and the scope for manipulation of the results suggests that an expert evaluation of design assessments is required. LCA studies are not easy to interpret as the results are provided in the form of indicators, and conclusions can only be drawn considering the local conditions where the road is to be constructed. It is therefore proposed that a technical evaluator specialised in LCA shall assist in preparing the ITT and, once tenders have been received, they will carry out a critical review of the LCA's for methodological choices, data quality and comparability.

The critical review is proposed to be carried out with reference to ISO 14044, section 6, ISO 14065 in case of carbon footprint and the following sections of the European Commission's Product Environmental Footprint (PEF) Recommendation (2013/179/EU):

- Critical review (section 9, p-68);
- Data collection checklist (Annex III);
- Data quality requirements (section 5.6, p-36);
- Interpretation of results (section 7, p-61).

The need of taking into consideration the project scale and economic value

Stakeholders suggested taking into consideration the project scale and economic value in order to decide about the inclusion of an LCA performance criterion. For example STA requires a carbon footprint if the investment projects is greater than approximately 5.5 M€. Another stakeholder suggested that this threshold should be defined by the NRA. A CF option as Core criterion and LCA option as Comprehensive criterion is proposed. Moreover, if the scale of the project is lower than a certain threshold, the contracting authority could decide not to require a CF or an LCA, but a simplified analysis on the CO_2e emissions from materials transportation (see section 2.3.4).

2.3.2.2 Summary of feedback from the 2nd round consultation of stakeholders

Stakeholder feedback received after the 2nd AHWG

The majority of stakeholders welcomed the proposed holistic approach. Some of them are more in favour of option 2 (LCA), because it takes into account the possible interaction between different impacts. However, here all the different options to be included in the ITT are described.

The main comments received from stakeholders during the 2nd AHWG and the 2nd round consultation can be summarised as follows:

- The *comparability of different pavement CF/LCA models* will make this criterion challenging to implement. It has to be ensured that *transparency of data* is prioritised.
- *The use phase* has to be considered within the CF/LCA model. There may be occasions where it is preferable to specify a higher CF/LCA for the road construction and maintenance phase if, over the whole life cycle, a greater benefit can be derived from lowering the rolling resistance and therefore reducing vehicle fuel consumption during the use phase. Careful selection of the functional unit could perhaps avoid the above issue, but would considerably increase the complexity of modelling.
- A *reference to EN 15804* has to be made where EPD data is mentioned.
- Reference to the ISO 14044, 4.3.4.3 does not allow for such a comparison and the same allocation procedure has to be used by different bidders. The *allocation methods for recycled or re-used materials* have to be in accordance with EN 15804.
- One stakeholder underlined that the proposed *impact category indicators* to be included, as a minimum, are well developed and accepted in the scientific community and that the inclusion of other indicators for which the methodology is still not mature, may lead to unfair comparisons among materials, and end up in disputes. However, on the contrary, many stakeholders highlighted that the full suite of impact category indicators in EN 15804 should be used. Moreover, in order to allow a fair comparison of the different proposals, a weighting system should be provided for each of the proposed indicators. Finally, some stakeholders highlighted that secondary resources (in mass) is not a LCA indicator and that it could be more relevant to use Abiotic Depletion Potential (ADP) as it is based on availability/scarcity.

2.3.2.3 Final criteria proposal

Core criteria	**Comprehensive criteria**
AWARD CRITERIA	
B14. LCA performance of the main road elements *If the impact of the road use phase is to be considered, this criterion shall be used in combination with the award criterion B13 Performance requirements on traffic fuel consumption due to rolling resistance.* *This criterion may only be applied where a Bill of Quantities[18] for a reference road is to be provided to bidders as the basis for comparison or where designs submitted by different bidders are to be compared during a competitive process.* *Additional technical guidance shall be followed during the procurement process, as provided in Annex A (Carbon Footprint option).* *A technical evaluator specialised in CF shall assist in preparing the ITT and shall carry out a critical review of the submissions.* Points will be awarded on the base of the improvement of the carbon footprint (CF) of the road including at least the	**B14. LCA performance of the main road elements** *If the impact of the road use phase is to be considered, this criterion shall be used in combination with the award criterion B13. Performance requirements on traffic fuel consumption due to rolling resistance.* *This criterion may only be applied where a Bill of Quantities[18] for a reference road is to be provided to bidders as the basis for comparison or where designs submitted by different bidders are to be compared during a competitive process.* *Additional technical guidance shall be followed during the procurement process, as provided in Annex B (LCA option).* *A technical evaluator specialised in LCA shall assist in preparing the ITT and shall carry out a critical review of the submissions.* Points will be awarded on the base of the improvement in the life cycle assessment performance (LCA) of the road including at least the main road elements listed in Table

18 Bill of Quantities is defined as *'a list of items giving detailed identifying descriptions and firm quantities of the work comprised in a contract'* (RICS 2011).

main road elements listed in Table (a) in comparison with a reference road *or* other competing designs.

The basis for the comparison shall be specified in the ITT.

Table (a) Scope of the road elements to be evaluated

New construction or major extension	Maintenance and rehabilitation
• Sub-grade, including earthworks and ground works • Sub-base • Base, binder and surface *or* concrete slabs • Additional ancillary road elements *(optional)*	• Base, binder and surface *or* concrete slabs

The performance shall be evaluated by carrying out a Carbon Footprint (CF) of the road in accordance with ISO 14067 or equivalent. The ITT shall specify the method that shall be used for the evaluation (see Annex A).

The bidder that shows the lowest carbon footprint will be ranked with the highest value.

Where analysis using the CF option is carried out prior to procurement of the main contractor, the successful tenderer shall prepare a handover document including the key assumptions and results with specific regard to:

- *earthworks and groundwork solutions;*
- *materials suggested to be used, techniques applied such as WMA, HWMA, CMA and recycled content, re-used content and/or by-products;*
- *CO_2e emissions per tonne of transported materials from production site to the worksite (baseline mass haul plan);*
- *% of recycling, re-use of excavated materials and construction and demolition waste on-site and off-site;*
- *Maintenance activities and frequencies.*

Verification:

The Design team *or* the DB tenderer *or* the DBO tenderer shall provide a bill of materials for the proposed design and the CF results, which shall be reported according to ISO 14067 or equivalent. The comparison with the reference road shall be written up in a concise technical report that compares the proposed design option(s) and calculates the improvement potential. The technical report shall describe how the "technical points to address" (as set out in Annex A) have been covered.

The handover document will be used by the contracting authority for the future ITT in case of separated design and build contracts or will be updated and further improved by the main construction contractor or the DB contractor or the DBO contractor before starting the construction phase.

The successful tenderer shall conclude the design phase

(b) in comparison with a reference road *or* other competing designs.

The basis for the comparison shall be specified in the ITT.

Table (b) Scope of the road elements to be evaluated

New construction or major extension	Maintenance and rehabilitation
• Sub-grade, including earthworks and ground works • Sub-base • Base, binder and surface *or* concrete slabs • Additional ancillary road elements *(optional)*	• Base, binder and surface *or* concrete slabs

The performance shall be evaluated by carrying out a Life Cycle Assessment (LCA) of the road in accordance with ISO 14040/14044. The ITT shall specify which of the following methods shall be used for the evaluation (see Annex B):

(i) Impact Category results: The aggregated characterisation results for each indicator obtained using the specified LCA method; or

(ii) LCA tool score: A single score obtained using a national or regional LCA tool used by public authorities;

In each case the methodology shall include, as a minimum, the Lifecycle Impact Category Indicators specified in Annex B.

Energy harvesting technologies shall be included in the LCA according to Annex B point d.

Where LCA analysis is carried out prior to procurement of the main contractor, the successful tenderer shall prepare a handover document including the key assumptions and results with specific regard to:

- *earthworks and groundwork solutions;*
- *materials suggest to be used, techniques applied such as WMA, HWMA, CMA and recycled content, re-used content and/or by-products;*
- *CO2e emissions per tonne of transported materials from production site to the worksite (baseline mass haul plan);*
- *% of recycling, re-use of excavated materials and construction and demolition waste on-site and off-site;*
- *Maintenance activities and frequencies.*

Verification:

The Design team *or* the DB tenderer *or* the DBO tenderer shall provide a bill of materials for the proposed design and the LCA results, which shall be reported according to ISO 14044. The comparison with the reference road shall be written up in a concise technical report that compares the proposed design option(s) and calculates the improvement potential. The technical report shall describe how the "technical points to address" (as set out in Annex

with the preparation of the handover document. *The successful DB tenderer or DBO tenderer shall prepare the handover document before starting the construction phase.* *The technical report shall be subject to a critical review by the contracting authorities appointed LCA technical evaluator. The critical review shall follow the guidelines in Annex C.*	B) have been covered. *The handover document will be used by the contracting authority for the future ITT in case of separated design and build contracts or will be updated and further improved by the main construction contractor or the DB contractor or the DBO contractor before starting the construction phase.* *The successful tenderer shall conclude the design phase with the preparation of the handover document.* *The successful DB tenderer or DBO tenderer shall prepare the handover document before starting the construction phase.* *The technical report shall be subject to a critical review by the contracting authorities appointed LCA technical evaluator. The critical review shall follow the guidelines in Annex C.*
CONTRACT PERFORMANCE CLAUSE	
Please refer to the general contract performance clause C1 Commissioning of the road construction.	Please refer to the general contract performance clause C1 Commissioning of the road construction**.**
Please refer to the general contract performance clause E4 Commissioning of the road maintenance**.**	Please refer to the general contract performance clause E4 Commissioning of the road maintenance**.**

Proposed technical annexes

Annex A

Supporting guidance for criterion* B14 *(core criterion): Option 1 – Carbon footprint (CF)

The award criterion B14 (core criterion) states that Carbon Footprint (CF) could be used by bidders in order to demonstrate how they have reduced the environmental impact of a road construction. This brief guidance note describes:

- When this criteria can be used;
- The rules required to ensure that bids are comparable; and
- The technical support required for bid selection.

All use of CF shall be carried out with reference to ISO 14067 or equivalent.

1.1 When can CF option 1 be used?

The use of criteria B14 is only recommended where a comparison can be made of improvement options against a reference road design and/or between different road designs. It is therefore relevant to the following procurement scenarios:

- Where the client already has a reference road design and bill of quantities that has been appraised in order to provide a guide price for comparison with bids;
- Where a design competition is to be used to encourage proposals of innovative road designs by design teams and/or contractors.

In these scenarios a CF analysis can be made an award requirement.

1.2 Will additional expertise be required to evaluate bids?

In any tender process for road construction and maintenance the procurer is likely to require supporting design and technical expertise in order to set requirements and evaluate designs. The procurer may therefore wish to call upon this expertise at two stages in the procurement process:

1. When putting together the design brief and performance requirements: Bidders shall be instructed on what technical requirements they should follow in order to ensure that the designs submitted are comparable.
2. When evaluating designs and improvement options: A technical evaluation of tenderers' responses to this criterion should be carried out in order to support the procurer.

A technical evaluator shall be required to carry out a critical review of each tenderer's CF analysis according to the guidance in Annex C.

1.3 What instructions should be given to bidders?

The following technical instructions should be incorporated into the ITT in order to ensure that bids are comparable. Where designs are to be evaluated against a reference road, this shall be clearly stated and the bill of materials provided.

Technical instructions for bidders using CF for road evaluations

Technical point to address	**What this means in practice**
a. Method and inventory data	The impact assessment method and life cycle inventory (LCI) data to be used by each design team shall, as far as possible, be specified to ensure comparability. Verified primary data may be used to supplement gaps following the guidance in ISO 14067 or equivalent, and for data from EPDs, ISO 14025 and EN 15804.. ISO 21930 could also be used as underlying standards, if relevant. The level of uncertainty shall be addressed by including: 1. a qualitative assessment of the uncertainties based on the sources of background data, how it was obtained or compiled and what kind of process and technology it represents; as well as 2. a quantitative assessment for the two most significant road elements identified from the analysis (see point d. and Tables a and b in criterion B14).
b. Comparison on the basis of functional equivalence	The following characteristics of the road shall be specified as a reference point for each design (see ISO 14067 or equivalent): - Relevant technical and function requirements, as described in the performance requirements; - The requested service life. A common functional unit shall be used to present the results (see ISO 14067 or equivalent).
c. Definition of the road life cycle and boundaries	The boundary for the analysis shall be cradle-to-grave including construction (including materials production and transportation) maintenance and operation and EoL. Allocation for recycled or re-used materials shall be made according to the following rules: – Input (product stage): according to the rules in ISO 14067 or equivalent; – Output (end of life or maintenance stages): according to the rules in EN 15804 section 6.4.3.
d. Road elements within the scope of the criteria	The scope of the criteria shall, as a minimum, comprise the following road elements: - Sub-grade, including earthworks and ground works; - Sub-base; - Base, binder and surface or concrete slabs; - Additional ancillary road elements (optional)
e. Lifecycle category indicator to be used for evaluation purposes	Global warming potential (GWP)

Annex B

Supporting guidance for criterion* B14 *(comprehensive criterion): Option 2 - LCA analysis

The award criterion B14 states how Life Cycle Assessment (LCA) could be used by bidders in order to demonstrate how they have reduced the environmental impact of the construction of a road. This brief guidance note describes:

- When this criterion can be used;
- The rules required to ensure that bids are comparable; and
- The technical support required for bid selection.

All use of LCA shall be carried out with reference to ISO 14040/14044.

2.1 When can LCA option 2 be used?

The use of criteria B14 is only recommended where a comparison can be made of improvement options against a reference road design and/or between different road designs. It is therefore relevant to the following procurement scenarios:

- Where the client already has a reference road design and bill of quantities that has been appraised in order to provide a guide price for comparison with bids;
- Where a design competition is to be used to encourage innovative road designs to be brought forward by design teams and/or contractors.

In these scenarios an LCA analysis can be used as an award criterion.

2.2 Will additional expertise be required to evaluate bids?

In any tender process for road construction and maintenance the procurer is likely to require supporting design and technical expertise in order to set requirements and evaluate designs. The procurer may therefore wish to call upon this expertise at two stages in the procurement process:

1. When putting together the design brief and performance requirements: Bidders shall be instructed on what technical requirements they should follow in order to ensure that the designs submitted are comparable.
2. When evaluating designs and improvement options: A technical evaluation of tenderers' responses to this criterion should be carried out in order to support the procurer.

A technical evaluator shall be required to carry out a critical review of each tenderers LCA analysis according to the guidance in Annex C.

2.3 What instructions should be given to bidders?

The following technical instructions should be incorporated into the ITT in order to ensure that bids are comparable. Where designs are to be evaluated against a reference road, this shall be clearly stated and the bill of materials provided.

Technical instructions for bidders using LCA for road evaluations

Technical point to address	What this means in practice
a. Method and inventory data	The impact assessment method and life cycle inventory (LCI) data to be used by each design team shall, as far as possible, be specified to ensure comparability. Verified primary data may be used to supplement gaps following the guidance in ISO 14040/14044, and for data from EPDs, ISO 14025 and EN 15804. ISO 21930 could also be used as underlying standards, if relevant. The level of uncertainty shall be addressed by including: 1. a qualitative assessment of the uncertainties based on the sources of background data, how it was obtained or compiled and what kind of process and technology it represents; as well as 2. a quantitative assessment for the two most significant road elements identified from the analysis (see point d. and Tables a and b in criterion B14).
b. Comparison on the basis of functional equivalence	The following characteristics of the road shall be specified as a reference point for each design (see ISO 14040/14044): – Relevant technical and function requirements, as described in the performance requirements; – The requested service life. A common functional unit or reference unit shall be used to present the results (see ISO 14040). Service lifetime shall be considered in the definition of the functional unit.
c. Definition of the road life cycle and boundaries	The boundary for the analysis shall be cradle-to-grave including construction (including materials production and transportation) maintenance and operation and EoL (see ISO 14040). Allocation for recycled or re-used materials shall be made according to the following rules: – Inputs (product stage): according to the rules in ISO 14044, Section 4.3.4.3; – Outputs (end of life or maintenance stages): according to the rules in EN 15804 section 6.4.3.
d. Road elements within the scope of the criteria	The scope of the criteria shall, as a minimum, comprise the following road elements: – Sub-grade, including earthworks and ground works; – Sub-base; – Base, binder and surface or concrete slabs; – Additional ancillary road elements (optional). When applied, energy harvesting technologies shall be included in the LCA as ancillary road elements and electricity generated during the operation phase shall be discounted from the energy consumed during this phase.
e. Lifecycle category indicators to be used for evaluation purposes	As a minimum the following impact category indicators, identified in EN 15804, shall be used: – Global Warming Potential (GWP);

	– Formation potential of tropospheric ozone photochemical oxidants (POCP); – Depletion potential of the stratospheric ozone layer (ODP); – Acidification potential of soil and water (AP); – Eutrophication potential (EP); – Abiotic Resource Depletion Potential for elements (ADP_elements); – Abiotic Resource Depletion Potential of fossil fuels (ADP_fossil fuels). Other indicators describing resource use, waste and output flows identified by EN 15804 can also be, partially or fully, included if they are not already covered by other GPP criteria, *e.g.*, a recycled content. A weighting system for the selected impact category indicators shall be applied in order to evaluate the overall score. This system shall be selected by the contracting authority on the basis of: – a suitable existing weighting system, such as the weighting systems adopted in some national LCA schemes; *or* – a weighting system proposed by the LCA technical evaluator (see Annex C). Where an LCA tool generates an aggregated scoring for the road, only the result for the impact categories identified in EN 15804 shall be taken into account.

Annex C

Brief for LCA technical evaluator

The role of the technical evaluator will be to assist the procurer in setting the ground rules for the tenderers, with reference to either Annex A or B, depending on the option chosen.

The technical evaluator shall propose and agree with the contracting authority the weighting of the LCIA indicator results, which shall be indicated in the ITT.

Once tenders have been opened, the technical evaluator will either:

(i) Carry out a critical review of the CFs for methodological choices, data quality and comparability; or

(ii) Carry out a critical review of the LCAs for methodological choices, data quality and comparability.

The critical review will be carried out with reference to ISO 14044, section 6, ISO 14065 in case of carbon footprint, and the following sections of the European Commission's Product Environmental Footprint (PEF) Recommendation (2013/179/EU):

- Critical review (section 9, p-68);
- Data collection checklist (Annex III);
- Data quality requirements (section 5.6, p-36);
- Interpretation of results (section 7, p-61).

<u>*Summary rationale for the final criteria proposal:*</u>

- According to the technical and environmental analysis of the preliminary report, materials production and transportation in construction and maintenance phases are the second most significant environmental impacts after the pavement-vehicle interaction in the use phase.
- Standards for environmental assessment methods in civil works are currently under development, and this makes the development of a holistic approach challenging. Most of the current methods focus on the carbon footprint and/or analyses of specific materials or road elements. However, some advanced tools already exist and are successfully employed in procurement procedures. The life cycle phases usually considered are construction (including materials production and transportation), maintenance (including operation) and EoL. The interaction between pavement and vehicle, and consequent consideration of the fuel consumption during the use phase, has not been taken into consideration yet. Therefore, a specific criterion on rolling resistance has been included in the criteria proposal.
- In conclusion, the evaluation of the improvement in life cycle performance of the main road elements is proposed as an award criterion. Two options appear possible for the evaluation of this improvement:

- Option 1: Carry out a Carbon Footprint (CF) (as Core criterion);
- Option 2: Carry out a Life Cycle Assessment (LCA) (as a Comprehensive criterion). In order to give procurers flexibility depending on the prevailing systems used in a MS, the following methods are included:

  2.1 Impact Category results: The aggregated characterisation results for each indicator obtained using the specified LCA method, representing a standalone LCA study;

  2.2 LCA tool score: A single score obtained using a national or regional LCA tool used by public authorities. This method is employed for example by Dubocalc.

- It is necessary to ensure comparability between the analyses by using the same LCIA method and life cycle inventory (LCI) data (option 1 and 2).
- The analysis in option 1 and 2 has to consider at least the main road elements, which have been identified according to the outcomes of the technical and environmental analysis. These elements are proposed because these are most acknowledged by design teams, forming the basis for the Bill of Quantities for a road. Moreover, if required, they can be disaggregated into constituent materials.
- Based on the feedback received from stakeholders, both CF/LCA options would need to be used in a way that recognised that there are relevant correlations with the use phase of the road. It is proposed to link the CF/LCA criterion with the criterion on traffic fuel consumption due to the rolling resistance criterion, in which it is proposed to evaluate the fuel consumption by means of the MIRAVEC tool or other equivalent assessment tools, where these are available.
- In Option 1 (CF), the bidder with the lowest Global Warming Potential will be ranked with the highest points. In Option 2 (LCA), based on a review of category indicators selected in LCA studies and the stakeholders feedback during the 2nd round consultation, the following impact category indicators identified in EN 15804 have been selected in order to reflect impacts during the production phase and to compare the bid designs - Global Warming Potential, the formation potential of tropospheric ozone photochemical oxidants, the depletion potential of the stratospheric ozone layer, the acidification potential of soil and water, the eutrophication potential, the depletion of abiotic resources-elements and of abiotic resources-fossil fuels. A weighting system of the selected impact category indicators shall be applied in order to evaluate the overall score. This weighting system must be defined by the contracting authority on the basis of suitable existing weighting systems, such as the weighting systems adopted in some national LCA schemes or the weighting system proposed by the LCA technical evaluator.

2.3.2.4 At what stage of the procurement process are the criteria relevant?

The evaluation of the performance of the main road elements has been proposed as an award criterion (both Core and Comprehensive) to be applied during the detailed design and performance requirements procurement phase. The *Design team* or the *DB tenderer* or the *DBO tenderer* shall provide a bill of materials for the proposed design. The comparison of the proposed design option(s) may only be applied where a bill of materials for a reference road is provided to bidders in the ITT as the basis for comparison or where designs submitted by different bidders are to be compared during a one or two stage competitive process. An LCA technical evaluator appointed by the contracting authorities shall provide a critical review.

The criteria classification, their reference numbers in the criteria document and the respective procurement phase can be cross referenced as follows:

Title of the criterion	Procurement phase	Criterion classification	Criteria typology	Reference number in the criteria document
LCA performance of the main road elements	B. Detailed design and performance requirements	Core and Comprehensive	Award criterion	B14
Commissioning of the road construction	C. Construction	Core and Comprehensive	Contract performance clauses	C1
Commissioning of the road maintenance	E. Maintenance and operation	Core and Comprehensive	Contract performance clauses	E4

2.3.3 Recycled content

2.3.3.1 Background technical aspects, discussion and rationale for the recycled content

Energy, water and material use are the three key areas where the construction industry needs to increase its resource efficiency. In Figure 19 the various ways in which efficient use of materials directly contributes to greater sustainability in construction are highlighted (WRAP, 2009).

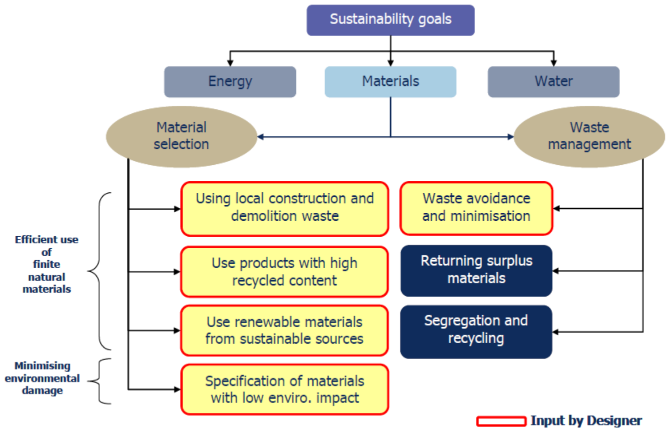


Figure 19: Materials selection and use is a key element of sustainable construction (WRAP, 2009).

According to the European Commission's Reference Document on Best Environmental Management Practice in the construction sector (EC, JRC 2012a), the use of materials with high recycled content is one of the best practices with the potential for greatest influence on resource efficiency in construction and should be taken into consideration by contracting authorities, project teams and relevant stakeholders during the procurement process. Moreover, in the above mentioned reference document it is claimed that recycled content can be checked along the supply chain, although in the absence of harmonised systems and protocols for declaration and traceability for most products and materials, this may be more difficult in some Member States.

Recycled content is defined by ISO 14021, which is a standard for Type II self-declarations by manufacturers, as the proportion, by mass, of recycled material in a product or packaging. In general, a reference to recycled content includes re-used products and materials. By-products as defined by art. 5 of the Waste Framework Directive (WFD, 2008) can also be classed as recycled content.

Employing more re-used and recycled material in construction is a way of making a significant contribution to resource efficiency by diverting materials from landfill and saving natural resources. Contractors and designers can make major improvements in materials efficiency, by minimising waste generation in construction, maximising the recycling rate, reusing materials and selecting construction products with a higher recycled content and lower embodied impacts. According to the guidelines of WRAP on recycled roads (WRAP, 2005a), benefits of using recycled materials in road include:

- Economic benefits: specific cost savings include the avoidance of waste disposal charges and landfill tax. Moreover, the use of recycled materials can significantly shorten the time needed for maintenance work and, therefore, decreasing traffic congestion.
- Environmental benefit: the use of recycled materials delivers clear environmental advantages by substituting virgin materials, decreasing energy consumption and diverting waste from landfill.
- Social benefit: reducing haulage activities, congestion and increasing road safety and cutting air pollution.

Guidance on materials with higher recycled content commonly used in road construction

According to the scenario assessment for resource efficiency in 2030 (EC, 2014) and to the results of the preliminary report, a guidance on materials with higher recycled content that are commonly used in road construction and maintenance, such as RAP, SCM's, recycled and secondary aggregates is proposed in Annex 4. Because a holistic approach over the life time of the pavement is applied, a single recycled content criterion that includes all the different recycled materials is proposed.

Defining the ambition level regarding recycled content

Most of the stakeholders supported the proposal of encouraging the use of re-used/recycled/recovered materials and by-products, such as RAP, SCM, recycled/secondary aggregates including by-products. Some stakeholders do not support requiring a minimum recycled content as a technical specification, because a prescription would interfere with the choice of contractors and might create adverse environmental impacts, such as leading to longer transport distances that offset the benefits of using recycled materials. However, the road construction sector appears a good candidate to require a minimum recycled content, considering the wide amount of quick-win options that can be chosen from, the huge amount of recycled materials and by-products available and the best practices that are already commonly applied in EU MSs such as RAP (according to EAPA 2013, more than 85% of reclaimed asphalt is re-used back into pavement materials) and recycled/secondary aggregates.

According to WRAP (2008b), recycled content can be calculated by value or by weight. A 'by value' focuses more attention on the wider range of opportunities where recovered materials can be used in construction products, while a 'by weight' focuses more on boosting the recycling of large amounts of materials. In order to make best use of the data on material quantities and costs commonly available to the contracting authority and the design team, the most practical indicator is the recycled content by weight in road construction. Calculation from mass to value is possible with data included in the cost plans and the Bills of Quantities (BoQ).

According to Rudus (2000), EC, JRC (2012a) and WRAP (2009), requiring a minimum of 10 to 15% recycled content by value for the project overall is broadly achievable. According to the WBCSD (2009), it is generally accepted that at least 20% of natural aggregate content can be replaced by recycled concrete aggregates for structural applications.

In WRAP's report *Delivering higher recycled content in construction projects* (2009), the findings of case studies undertaken for a broad range of building and infrastructure types are presented. In detail, this underlines that most infrastructure contains an overall percentage of 8-36% recycled content by value using standard products. Moreover, by using cost-neutral good practice and readily available construction products with higher recycled content, an overall percentage of 25-49% recycled content by value could be easily obtained.

As reported in Table 15, data compiled from a number of different projects and studies illustrates that the level of recycled content in different construction materials can vary widely from very low levels, according to standard materials used in the market, to very high levels which can be considered to represent good or best practices in the market.

Standard practice represents the baseline level at which the lowest recycled content is normally achieved. Good practices with higher level of recycled content are available in the market and are achievable at no or limited additional costs. Moreover, information is given also on the best practice level, in which the highest recycled content is generally achievable, based on the evidence reviewed, at additional cost. Even though it is not possible to generalise the results provided by these examples, they provide an indication of the feasible level of recycled content in currently used construction materials and products. It is necessary to consider cost in order to establish the potential for recycling demolition materials either on-site or recovery at recycling facilities.

This example data shows that 10% recycled content by weight of the total BoQ could be reached with minimal effort including RAP and recycled/secondary aggregates in bound and unbound applications. Moreover, by setting this minimum requirement, construction clients can motivate their design team and contractors to become aware of their current performance and then identify the most significant opportunities to improve that performance (WRAP, 2008b). By seizing the available opportunities to increase recycled content through the use of cost competitive, readily available products (*i.e.*, 'good practice' at no extra costs), levels exceeding 15–20% by value are common.

Choosing to use products with a higher recycled content and to achieve a high level of performance for the total BoQ is more challenging. For example, specifications for concrete and asphalt may imply higher levels of quality control on performance from suppliers and monitoring on site.

In the draft Italian criteria on road construction and maintenance, specific recycled contents are required in different courses (minimum of 30% in the sub-base and road-base, 30% in the base, binder and surface courses. Moreover, a specific technical specification is proposed, with the employment of CMA in the base course with a minimum recycled content of 50%).

Table 15: Example of recycled content used in construction materials in different practices.

Material		Standard practice (% mass)	Good practice (% mass)	Best practice (% mass)
Aggregates	Coarse aggregates in concrete	0 [c]	20 [a, b, c]	100 [c]
	Coarse aggregate in low strength mass concrete	0 [c]	30 [c]	100 [c]
	Unbound in civil applications	0-50 [c]	25-80 [c]	100 [c]
	Aggregates in hydraulic bound and cement bound materials	0 [c]	60 [c]	100 [c]
	Aggregate in bituminous bound pavements (off-site)	0 [c]	10 [c]	40 [c]
	Aggregate in bituminous bound pavements on-site/off-site cold process	100 [c]	100 [c]	100 [c]
	Aggregates in road sub-base		100 [e]	
	Recycled concrete aggregates	30 [f]		
Asphalt	HMA and/or WMA – RAP hot mix recycling off-site		30-80 [b]	
	HMA and/or WMA – RAP hot mix recycling of off-site		30-50 [b]	
	HMA and/or WMA– RAP cold method in hot mix recycling off-site		10-40 [b]	
	CMA – Cold mix recycling in a stationary plant		90 [b]	
	HMA and/or WMA - on-site hot mix recycling of RAP			100 [b]
	CMA – on-site cold mix recycling of RAP	100 [b, c]	100 [b, c]	100 [b, c]
Concrete	Hydraulic bound material and cement bound material	0 [c]	50 [c] 10-20 [b]	98 [c]
	Cast in situ reinforced structural concrete (max C25-C30)	15-24 [c]	30-32 [c]	44-90 [c]
	Cast in situ reinforced structural concrete (higher than C30)	0 [c]	7 [c]	26 [c]
	Pre-cast reinforced structural concrete	20 [c]	22 [c]	23 [c]
	Trench fill foamed concrete	0 [c]	40 [c]	95 [c]
Inert	Sub-soil	75 [e]	95 [e]	100 [e]
	[a] EC JRC 2012 [b] Biois, EC 2011 [c] WRAP 2008b [d] WRAP 2009	[e] ICE Protocol 2008 [f] WBCSD 2009		

On the basis of the information reviewed, criteria could be proposed to encourage the further incorporation of recycled content into the main road elements (either individually or in total) as defined in section 2.3.2. Recycled content have not been differentiated proposing different requirements for different courses in order to allow flexibility and allow the design team to propose the most sustainable solution.

- Many stakeholders have suggested to delete the requirement of a minimum recycled content, because in some MSs, surface courses such as porous asphalt and SMA cannot contain a minimum recycled content and because of a potential increase of the transportation distances. The minimum recycled content as a technical specification has therefore been deleted in the final proposal.
- As a Core award criterion, it could be proposed to give points to incorporation of recycled content (including also re-used content and/or by-products) greater than a minimum of 15% by weight of the total BoQ.
- As a Comprehensive award criterion, it could be proposed to give points to incorporation of recycled content (including also re-used content and/or by-products) greater than a minimum of 30% by weight of the total BoQ.

One stakeholder highlighted that the term by-product makes implicitly reference to the legal status of materials and suggested to replace it by "manufactured aggregates" or "co-products" and to name the set of recycled or re-used materials, manufactured aggregates and/or co-products as *alternative material*. However alternative materials are not defined in the WFD and, therefore, it is proposed to maintain the previous definition on recycled content, re-used content and/or by-products, according to the terminology used in the EC, JRC (2012a) and WRAP (2009) documents.

During the 2nd round consultation many stakeholders suggested to distinguish between recycled and re-used contents, with priority given to the latter. It could be concluded that a generic rule valid across the EU-28 would be difficult to define and justify based on the lack of real case studies. Furthermore, due to the specificities of each road project, it would be extremely challenging to apply a general rule across all road projects. Nonetheless, such a prioritization may be explicitly indicated by the contracting authority according to the specific local conditions in which the road is designed and built.

Taking into account the transport impacts

In the 2nd AHWG and the 2nd round consultation, stakeholders highlighted the importance of taking into account the transport impacts linking the recycled content criterion to materials transportation, considering the mode of transport and CO_2 emissions. It was highlighted that recycled content may not always provide an environmental improvement because bulk materials, such as recycled coarse aggregates, may have to be transported over longer distances than virgin materials, for example natural coarse aggregates.

For this reason, it is important to take account of the possible trade-off by either:

- At the most basic level it would be possible to require consideration of only the CO_2e emissions from materials transportation *i.e.*, criterion B14 (see scenario 3 in Figure 20 and Section 2.3.4);
- An intermediate level would be to combine the CO_2e emissions from materials transportation with a recycled content requirement (see scenario 2 in Figure 20); or
- At the most ambitious level to evaluate the impacts holistically by including within the ITT a criterion on the life cycle impacts of materials *i.e.*, criterion B14 which is CF/LCA based (see scenario 1 in Figure 20).

The preferred option would be the most ambitious, with the mode of transport considered within the life cycle inventory data analysed. However in both other options the mode of transport would at least be taken into account to some extent. This approach is considered to allow more flexibility for contracting authorities to choose the ambition level. The proposed interrelationship between the criteria options is illustrated in Figure 20

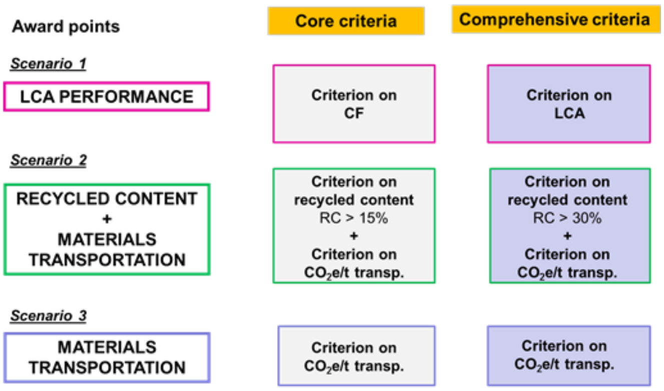


Figure 20: Scheme on the interrelation between recycled content criterion and CF/LCA criterion *or* materials transportation criterion.

Although it is proposed that if criterion B14 is used then a criterion on recycled content shall not be used, it is considered that there may be local circumstances that still warrant the setting of specific recycled content requirements in an ITT. This may, for example, reflect local natural resource constraints as set out in a minerals plan, or landfill diversion targets which may reflect local waste management constraints as set out in a waste plan.
Moreover, it has been suggested to make reference to standards on the responsible sourcing of materials, which are not currently used in all MSs. The inclusion of such reference appears therefore premature.

Monitoring recycled content during construction

The records on the achieved levels of recycled content, carried out by the main construction contractor or the DB contractor or the DBO contractor, should be kept up to date and be accurate to support verification. Information on the level of recycled content should be periodically updated to reflect the emerging design and specification. The frequency with which the recycled content of the road needs to be reviewed will depend on the scale of any design changes that occur. Increasing the proportion of the materials used in a project that come from a recycled source is a relatively simple, practical and cost-neutral way of showing a measurable contribution to more sustainable construction.

Verification

Under the Construction Products Regulation (CPR - 305/2011/EU) several products with recycling potential are covered by harmonised European standards (hEN). Currently, these standards are covering the performance of a product per se (*e.g.*, structural stability, fire safety, emission of dangerous substances) no matter if the materials used are primary or secondary materials. However, the ongoing discussion at EU and national level on covering environmental performance in hENs and the development of horizontal product category rules (PCR) in a European standard (15804) has motivated several technical committees in CEN to assess if and how reliable information on recycled content could be addressed in specific hENs for construction products.

Products covered by harmonised European standards that might have significant potential of using recycled materials are:

- Rc = Concrete, concrete products, mortar & concrete masonry units.
- Ru = Unbound aggregate, natural stone & hydraulically bound aggregate.
- Rb = Clay masonry units (i.e. bricks and tiles), calcium silicate masonry units & aerated non-floating concrete.
- Rg = Glass.

Having the above information reported makes the identification of the recycled content easier. In the UK, for example, the application of an End-of-Waste Quality Protocol for recycled and secondary aggregates (DEFRA, WRAP, 2013) has provided a benchmark for standards, giving aggregate users the confidence that recycled and secondary materials are of the required quality and are equivalent to primary, or natural, materials supporting an increased use of recycled content in the construction sector.

Whilst an annual production average for a dedicated production line is understood to be readily verifiable, further feedback has been collected from stakeholders on whether batch production to a specified content can be accurately verified. An approach based on a mass balance for a product batch from which deliveries are made to a site (for example, ready mix concrete or asphalt for which samples from each batch are tested prior to dispatch) is proposed. A batch is considered as a quantity of goods manufactured by the same process under the same conditions and labelled in the same manner.

For example, according to harmonized European asphalt product standards, the Type Test Report (EN 13108-20) shall include information on the identification of the producer and the mixing plant, constituent materials (aggregates, binder, filler, additives), the mix design formulation, the temperature, the test results and categories with which conformity is being declared. A scheme of a production plant in which different constituent are mixed to produce a product batch that is delivered to site is represented in Figure 21. The Factory Production Control (EN 13108-21) shall control the conformity of products to mix formulation documented according to EN 13108-20 and includes a quality control plan, control procedures, inspection and testing on both incoming constituent materials and finished bituminous mixtures. Furthermore, the harmonized European asphalt product standards (EN13108 series) require that the percentage of reclaimed asphalt to be declared in the Type Test report. This, in combination with the Type Test report standard (EN 13108-20) and Factory Production Control standard (EN 13108-21) and the presence of Notified Bodies, is sufficient to provide a sufficient level of certainty that the declared percentage of reclaimed asphalt is delivered. A similar system is in place for other materials such as the ready mix concrete.

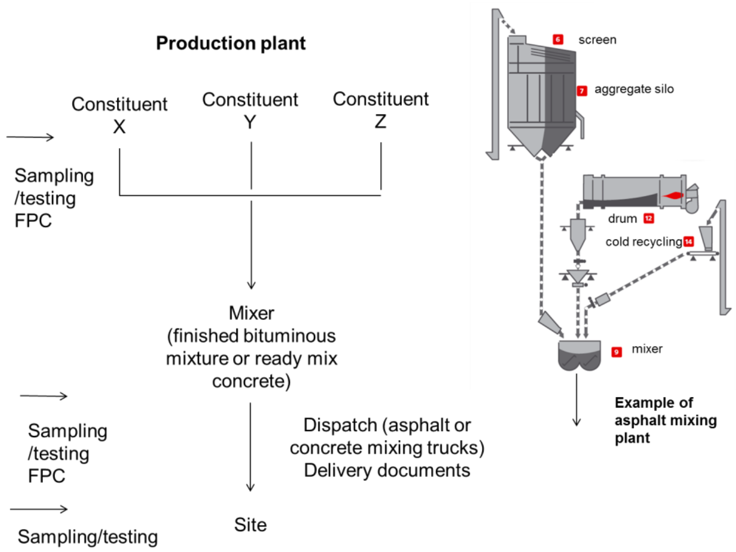


Figure 21: Scheme of a production plant and dispatch to site.

It is therefore proposed that, during the design phase, the proportional contribution of the recycled content and/or re-used content to the overall weight of the specified road elements has to be quantified. The design team has to describe how the total recycled content will be calculated and verified, including, as a minimum, batch documentation, factory production control documentation and delivery documentation, and how the third party verification will be arranged during the construction phase. In this latter phase, all the certificates providing information would have to be collated, including product data sheets, batch documentation, *i.e.*, data from mix design, and supporting certificates for recyclates. The verification would therefore need to be conducted by auditing of the manufacturer's process control records. Following feedback from stakeholders, the third party verification has been withdrawn from the design phase, because it can be realistically arranged only during the construction phase, when the batch documentation, factory production control documentation and delivery documentation, *etc.*, will be physically produced.

2.3.3.2 Summary of feedback from the 2nd round consultation of stakeholders

Stakeholder feedback received after the 2nd AHWG

The main feedback received from stakeholders during the 2nd round consultation can be summarised as following:

- In order to stimulate a more holistic approach and the use of performance based indicators, the ERA NET ROAD Energy Efficiency tools[19] might be used, but this might require harmonization of tools and databases. A specific reference is made to the ongoing RECYCLING[20] (CEDR Call 2012) and EDGAR[21] (CEDR Call 2013) projects, which could contribute to this harmonization.
- The *requirement of a minimum recycled content as a technical specification* has to be deleted. First, of all, in some MSs, surface courses such as porous asphalt and SMA cannot contain a minimum recycled content due to strict requirements for the aggregate grading curve used in those mixtures (see the RECYCLING project). Secondly, a minimum requirement might lead to an increase in transportation distances.
- The *local availability and transportation of materials* has to be considered. As highlighted in the previous point, a stronger link with the criterion on materials transportation has been requested. It has also been suggested to award points for carrying out an analysis of local availability of recycled material or, alternatively, for using a responsible sourcing scheme, such as BES 6001, which includes aspects such as traceability, environmental management and social responsibility.
- A *distinction* has to be made *between re-used content (use for the same purpose) and recycled content (use for a different purpose),* with a higher priority being given to re-use in accordance with the WFD hierarchy.

2.3.3.3 Final criteria proposal

Core criteria	**Comprehensive criteria**
AWARD CRITERIA	
B15. Incorporation of recycled content *It is recommended to consider combining this criterion with the criterion B16., but should not be used if criterion B14. is selected*[22]*.* The contracting authority shall award points to tenderers	**B15. Incorporation of recycled content** *It is recommended to consider combining this criterion with the criterion B16., but should not be used if criterion B14. is selected*[22]*.* The contracting authority shall award points to tenderers

19 http://www.eranetroad.org/index.php?option=com_content&view=article&id=111:2011-energy&catid=31:standard&Itemid=46

20 http://www.cedr.fr/home/index.php?id=262&dlpath=CEDR%20Call%202012%20Recycling&cHash=bec8c83b7e996a1f1eef4411b4d2ee48

21 http://www.cedr.fr/home/fileadmin/user_upload/en/Thematic_Domains/Strat_plan_3_2013-2017/TD1_Innovation/I1_Research/TGR_TPM/CEDR_Call_2013_information_June2014.pdf

22 If specific local conditions and planning policies support the use of recycled content, the contracting authority can evaluate, on a case by case basis, the possibility to include a criterion on recycled content within the ITT alongside the holistic criterion B14 CF/LCA. The assumptions and life cycle inventory data relating to the production and construction phase of the recycled materials would need to be included in the response to B14.

that achieve greater than or equal to 15% by weight of the recycled content, re-used content and/or by-products [23] for the sum of the main road elements in Table (c).

The minimum content requirement for award could be set higher if agreement is reached with the design team prior to tendering for the main contractor.

The contracting authority may decide to allocate more points to the re-used content rather than to the recycled content according to the specific local conditions

Table (c) Scope of the road elements to be evaluated

New construction or major extension	**Maintenance and rehabilitation**
▪ Sub-grade, including earthworks and ground works; ▪ Sub-base; ▪ Base, binder and surface *or* concrete slabs.	▪ Base, binder and surface *or* concrete slabs.

The recycled content as well as the re-used content shall be calculated on the basis of an average mass balance of re-used, recycled materials and/or by-products according to how they are produced and delivered to site (*as applicable*):

- For each ready mix batch from which deliveries are dispatched to the construction site in accordance with standards on:
  - aggregates EN 13242, EN 13285;
  - asphalt pavement EN 13043, EN 13108-1, EN 13108-2, EN 13108-3, EN 13108-4, EN 13108-5, EN 13108-6, EN 13108-7, EN 13108-8;
  - concrete pavement EN 206, EN 12620, EN13877;
  - hydraulically bound granular mixtures EN 14227 part 1 to 5;
  - stabilised soil EN 14227 part 10 to 15.
- On an annual basis for factory made slabs and elements with claimed content levels in accordance with EN 12620 and EN 206, EN 13877 and national legislation.

Verification:

The design team *or* the DB tenderer *or* the DBO tenderer shall propose the recycled content, re-used content and/or by-products quantifying the proportional contribution of the recycled content and/or re-used content to the overall weight of the specified road elements, based on the information provided by the producer(s) of the construction material.

The design team *or* the DB tenderer *or* the DBO tenderer shall describe how the recycled content will be calculated and verified, including, as a minimum, batch documentation as the Type Test report, factory production

that achieve greater than or equal to 30% by weight of the recycled content, re-used content and/or by-products[23] for the sum of the main road elements in Table (d).

The minimum content requirement for award could be set higher if agreement is reached with the design team prior to tendering for the main contractor.

The contracting authority may decide to allocate more points to the re-used content rather than to the recycled content according to the specific local conditions

Table (d) Scope of the road elements to be evaluated

New construction or major extension	**Maintenance and rehabilitation**
▪ Sub-grade, including earthworks and ground works; ▪ Sub-base; ▪ Base, binder and surface *or* concrete slabs.	▪ Base, binder and surface *or* concrete slabs.

The recycled content as well as the re-used content shall be calculated on the basis of an average mass balance of re-used, recycled materials and/or by-products according to how they are produced and delivered to site (*as applicable*):

- For each ready mix batch from which deliveries are dispatched to the construction site in accordance with standards on:
  - aggregates EN 13242, EN 13285;
  - asphalt pavement EN 13043, EN 13108-1, EN 13108-2, EN 13108-3, EN 13108-4, EN 13108-5, EN 13108-6, EN 13108-7, EN 13108-8;
  - concrete pavement EN 206, EN 12620, EN13877;
  - hydraulically bound granular mixtures EN 14227 part 1 to 5;
  - stabilised soil EN 14227 part 10 to 15.
- On an annual basis for factory made slabs and elements with claimed content levels in accordance with EN 12620 and EN 206, EN 13877 and national legislation.

Verification:

The design team *or* the DB tenderer *or* the DBO tenderer shall propose the recycled content, re-used content and/or by-products quantifying the proportional contribution of the recycled content and/or re-used content to the overall weight of the specified road elements, based on the information provided by the producer(s) of the construction material.

The design team *or* the DB tenderer *or* the DBO tenderer shall describe how the recycled content will be calculated and verified, including, as a minimum, batch documentation as the Type Test report, factory production

23 A by-product is defined in art. 5 of the Waste Framework Directive as '*A substance or object, resulting from a production process, the primary aim of which is not the production of that item....*'

control documentation and delivery documentation, and how the third party verification will be arranged during the construction phase.	control documentation and delivery documentation, and how the third party verification will be arranged during the construction phase.
CONTRACT PERFORMANCE CLAUSES	
C3. Incorporation of recycled content When materials are delivered to the work site, recycled content claims with clear traceability shall be verified for each batch[24] of product. The main construction contractor *or* the DB contractor *or* the DBO contractor shall verify claims by providing either: - an independent third party certification of the traceability and mass balance for the product and/or recyclate; - *or* equivalent documentation provided by producer(s).	**C3. Incorporation of recycled content** When materials are delivered to the work site, recycled content claims with clear traceability shall be verified for each batch[24] of product. The main construction contractor *or* the DB contractor *or* the DBO contractor shall verify claims by providing either: - an independent third party certification of the traceability and mass balance for the product and/or recyclate; - or equivalent documentation provided by producer(s).
E5. Incorporation of recycled content *The same as C3.*	**E5. Incorporation of recycled content** *The same as C3.*

Summary rationale for the final criteria proposal:

- The use of materials with high recycled content is one of the practices with the greatest potential to improve resource efficiency in the construction sector. This practice contributes to sustainable development by diverting materials from landfill and saving natural resources.
- The findings of case studies undertaken for a broad range of civil works have shown that most roads have greater than 10% recycled content by weight using standard products. Moreover, by using cost-neutral good practice and readily available construction products with higher recycled content, an overall percentage of 15-30% recycled content by weight could be obtained.
- On the basis of the information reviewed, to encourage the further incorporation of recycled content into the main road elements, points could be proposed in proportion to incorporation of recycled content (including also re-used content and/or by-products) greater than a minimum of 15% by weight as a Core award criterion and greater than a minimum of 30% by weight as Comprehensive award criterion.
- The estimation of the recycled content should be kept up to date and be accurately reported for verification purposes. The potential for third party verification of recycled or re-used content reported in datasheets by suppliers would be required in order to provide assurance.
- Information on the level of recycled content should be periodically updated to reflect the emerging design and specification, the source and verification method.
- It is recommended to address the potential trade-off from CO_2 emissions associated with the transport of recycled aggregates by combining this criterion with criterion B16, which is designed to address transport emissions, also considering the mode of transport. The relative weighting of the two criteria should ensure effective competition between potential suppliers whilst also encouraging tenders that deliver an overall environmental benefit.
- If a contracting authority decides to reward recycled or re-used content (see B15) or reduced transport emissions (see B16), it should consider setting criteria that take into account the specific conditions in the local market for construction materials. This may need to reflect the local availability of processing plant, and therefore recycled materials, as well as transport infrastructure, with a focus on low carbon bulk transport modes such as rail or shipping.

24 "Batch" means a quantity of uniformly labelled product manufactured by the same mixing plant, under the same conditions according to a set mix design with the same input materials.

2.3.3.4 At what stage of the procurement process are the criteria relevant?

First it has to be underlined that, to fully benefit from the use of recycled materials, good practice must be adopted at the earliest possible stage (preliminary scoping and feasibility), and targeted requirements on recycled content should be communicated between the contracting authority and contractor and passed down through the supply chain across all project phases. The public authority's strategic objectives and procurement policy on waste minimization have to be taken into consideration. In this phase, an important activity could be the definition of the sustainable supply mix (SSM) of aggregates: *a procurement of aggregates from multiple sources, including environmental considerations*. An early contractor involvement (ECI) could provide early opportunities in order to bring their knowledge in the strategic planning phase. The incorporation of recycled content has been proposed as an award criterion. These criteria have to be applied during the detailed design and performance requirements procurement phase. Moreover, recycled content has to be verified during construction of the road or maintenance procurement phase by means of a contract performance clause.

In detail, during the detailed design and performance requirements procurement phase, the *Design team* or the *DB tenderer* or the *DBO tenderer* shall quantify the proportional contribution of the recycled content to the overall weight of the road elements. Moreover, the specific road elements and proposed products to be used shall also be specified within the detailed design. The ordering and delivery to site of these road elements shall later be verified during the construction of the road or maintenance procurement phase by the main *construction contractor or* the *DB contractor or* the *DBO contractor* by providing an independent third party certification of the chain of custody and mass balance for the product and/or recyclate *or* equivalent documentation provided by suppliers and processors.

The criteria classification, their reference numbers in the criteria document and the respective procurement phase can be cross-referenced as follows.

Title of the criterion	Procurement phase	Criterion classification	Criteria typology	Reference number in the criteria document
Incorporation of recycled content	B. Detailed design and performance	Core and Comprehensive	Award criterion	B15
Incorporation of recycled content	C. Construction	Core and Comprehensive	Contract performance clauses	C3

2.3.4 Materials transportation

2.3.4.1 Background technical aspects, discussion and rationale for CO_2e emissions from materials transportation

Transportation of large-volume, high-weight materials, such as aggregates (natural, recycled or secondary), was highlighted in the preliminary report as a potential environmental hot spot, particularly as there may be trade-offs in the transportation of recycled or by-product materials. Aggregates, concrete (typically composed of about 75-80%$_w$ of aggregates) and asphalt (typically composed of about 90-95%$_w$ of aggregates) easily account for over 90%$_w$ of all transported material mass. Transport of these materials is typically by lorry, which results in fuel-related emissions that are generally greater than or equal to those for the production of such materials. If these materials are moved over distances greater than 25 km (Blengini and Garbarino, 2010), the resulting emissions can contribute significantly to the environmental impacts of the production phase for the main road elements.

From data gathered from Wang (2012b), Pacheco-Torgal et al. (2013) and Badino et al. (2007), it has been estimated that if transport distances by lorry were to rise from 25 km to 50 km or 200 km, then the transport contribution to the Global Warming Potential (CO_2e) of an asphalt mix delivered to a construction site could raise, indicatively, from 6% to 13-29% and the transport contribution of the unbound aggregates used in the road base and sub-base could rise, indicatively, from 50% to 66-89%.

Marinkovic et al. (2014) highlights for concrete mix that whilst aggregate production can account for 0.8% and 5.4% across all impact categories, the variation in transport distances can also be a significant consideration, with the comparable contribution to the Global Warming Potential (CO_2e) impact category ranging from 3% to 20% depending on the distances. A further interrogation of the data suggests that there may be less potential for variation, but nonetheless still one that is potentially significant. This suggests that if transport distances by lorry were to rise from 25 km to 50 km or 200 km then the transport contribution to the Global Warming Potential (CO_2e) of a concrete mix delivered to a construction site could rise, indicatively, from 1.3% to 2.5-10%. As a result, the potential benefits of switching from natural to recycled coarse aggregate could be eclipsed by greater transport emissions. This finding is supported by recent LCA research for the Cement industry (European Cement Research Academy, 2015).

In the first draft of the technical report a separate criteria area for materials transportation was proposed. According to Parikka-Alhola and Nissinen (2008) a clause penalizing contractors solely on the basis of the distance they travel to deliver the goods would perhaps be discriminatory. Many stakeholders pointed out that there is no need to take into account materials transportation distances as a stand-alone criterion, because transport cost usually leads to a reduction in transport distance. According to stakeholders, recycled materials and by-products, have usually lower transport distances than virgin materials.

According to other literature sources (Pacheco-Torgal et al., 2013) (WRAP, 2011) (WRAP, 2006), it might not always be the case that the transport distance, and consequently the costs, of recycled material, are lower than the ones for natural construction materials and that other additional factors, such as the embodied carbon and the transport mode, influence both the costs and the environmental impacts. Large-volume, high-weight construction materials with relatively low embodied carbon, such as natural, recycled or secondary aggregates, can have a disproportionately high contribution to CO_2e emissions from transport and the mode of transport is therefore a relevant aspect to be considered. With respect to the mode, transport by road can be four times more carbon intensive than rail and thirty seven times more carbon intensive than bulk shipping (WRAP 2011).

Another issue is the availability of treatment plants for the receiving and crushing of construction and demolition waste. This may vary depending on the demand in the local area for crushed recycled aggregate, as well as having the potential to push up prices if longer distance lorry transportation is required (WRAP, 2006). In this case, and in order to avoid trade-offs in the form of higher CO_2 emissions, there would be the need to support lower emission modes of bulk transport such as rail or shipping. Rail infrastructure can, for example, be used to address imbalances between supply and demand across regions (Sustainable aggregates, 2008).

Lehtiranta et al (2012) and Sanchez et al. (2013) suggested the integration of criteria on the estimation and monitoring of the total fuel consumption and haulage distance per unit volume of material transported. Alternatively, they suggested the inclusion of GHGe estimation of materials amount and transportation as part of the standard tender documentation requirements, using either in-house or internationally available GHGe calculators. ENCODE Protocol (2013), ICE Demolition Protocol (ICE, 2008), DEFRA's Guidelines for Company Reporting on Greenhouse Gas Emissions[25,] WRAP's CO_2 Estimator Tool[26,] the Flemish "Carbon Free-Ways"[27] developed or are developing Carbon footprint approach in order to encourage the use of recycled materials and minimising associated haulage movements.

In Sweden, Trafikverket has set requirements on trucks and working machines[28.] Some working machines already use a GPS to measure quantities of excavated and filled soils (not mandatory). Equipping all working machines with accurate fuel gauges is a matter of costs and benefit. Measuring fuel consumption within maintenance activities has been discussed in the ELSA project (Meijer et al., 2014).

A holistic approach has been proposed in section 2.3.2, therefore transportation of road materials and the movement of soil and stones on-site and off-site during the earthworks are already included in the Carbon Footprint or the LCA performance requirement. If procurers will decide to not assign points on the CF or LCA-performance approach, alternative award criteria are proposed on the evaluation of the CO_2e emissions / tonnes of material transported. It is recommended combining this criterion with the criterion on recycled content in order to achieve an overall environmental benefit, as highlighted in section 2.3.3.1

Considering the feedback received during the 2nd round consultation and in order to prevent the de facto exclusion of non-local suppliers, it is proposed to focus the baseline mass haul plan on the CO_2e emissions instead of tonne·km of transported materials. Therefore, the transportation distances could be indicated by the design team in the baseline mass haul plan only if already identifiable in the design phase. It will be a specific task of the main contractor to propose, and possibly improve, the mass haul plan in which the CO_2e emissions per tonne of transported materials, as determined in the design phase, are not exceeded.

25 DEFRA https://www.gov.uk/measuring-and-reporting-environmental-impacts-guidance-for-businesses

26 WRAP http://aggregain.wrap.org.uk/sustainability/try_a_sustainability_tool/co2_emissions.html

27 Agentschap Wegen en Verkeer http://www.abr-bwv.be/sites/default/files/03_3a%20Van%20Troyen.pdf and http://www.wegenenverkeer.be/parallelle-sessies/sessies-pm/carbon-free-ways/item/carbon-free-ways.html

28 http://www.trafikverket.se/Foretag/Upphandling/Sa-upphandlar-vi/Forfragningsunderlag/Kravdokument/Miljokrav-i-entreprenader/

2.3.4.2 Summary of feedback from the 2nd round consultation of stakeholders

Stakeholder feedback received after the 2nd AHWG
- By choosing the CO_2e emission per tonne of transported materials as an indicator, the transport mode (road, rail, inland waterways, *etc.*) is implicitly included. - This criterion (or the CF/LCA results) has to be integrated with the recycled content criterion in order to balance the awarded points or to require a sensitivity analysis to weigh up the trade-offs between recycled content and CO_2 emissions (or CF/LCA results). - In the design phase is not advisable limiting the contractors' ability to issue a competitive bid, as some contractors might have advantages due to special rights or ownership of local mixing plants, quarries etc and it might be more appropriate to use a qualitative sustainability plan.

2.3.4.3 Final criteria proposal

<table>
<tr><th>Core criteria</th><th>Comprehensive criteria</th></tr>
<tr><td colspan="2">AWARD CRITERIA</td></tr>
<tr>
<td>
B16. Performance requirements for CO_2e emissions from the transportation of aggregates
This criterion should not be used where criterion B14 is applied. It is recommended combining this criterion with B15. in order to achieve an overall environmental benefit. This should always be done based on an understanding of the local market conditions and by establishing and clearly specifying in the ITT a weighting of the two criteria that will ensure effective competition and reward bids that offer the best overall environmental performance.
Points will be awarded in proportion to the reduction in the CO_2e emission/tonne of aggregates[29] for use in the production of the main road elements listed in Table (e). The method and tool to be used to calculate the CO_2e emissions from the transportation shall be specified in the ITT.
In some Member States there may already be permitting requirements and associated tools made available for the calculation of transport-related CO_2 equivalent emissions, in which case the bidders shall declare the emissions based on using these rules.
A maximum target for CO_2e emissions/tonne of aggregates transported could be set by the contracting authority based on information from the design team. This, together with their assumptions and rules, shall be included in the ITT for the main contractor.
Table (e) Scope of the road elements to be evaluated
<table>
<tr><th>New construction or major extension</th><th>Maintenance and rehabilitation</th></tr>
<tr><td>▪ Sub-grade, including earthworks and ground works;
▪ Sub-base;
▪ Base, binder and surface or concrete slabs;
▪ Additional ancillary road elements (optional).</td><td>▪ Base, binder and surface or concrete slabs.</td></tr>
</table>
</td>
<td>
B16. Performance requirements for CO_2e emissions from the transportation of aggregates
This criterion should not be used where criterion B14 is applied. It is recommended combining this criterion with B15. in order to achieve an overall environmental benefit. This should always be done based on an understanding of the local market conditions and by establishing and clearly specifying in the ITT a weighting of the two criteria that will ensure effective competition and reward bids that offer the best overall environmental performance.
Points will be awarded in proportion to the reduction in the CO_2e emission/tonne of aggregates[29] for use in the production of the main road elements listed in Table (f). The method and tool to be used to calculate the CO_2e emissions from the transportation shall be specified in the ITT.
In some Member States there may already be permitting requirements and associated tools made available for the calculation of transport-related CO_2 equivalent emissions, in which case the bidders shall declare the emissions based on using these rules.
A maximum target for CO_2e emissions/tonne of aggregates transported could be set by the contracting authority based on information from the design team. This, together with their assumptions and rules, shall be included in the ITT for the main contractor.
Table (f) Scope of the road elements to be evaluated
<table>
<tr><th>New construction or major extension</th><th>Maintenance and rehabilitation</th></tr>
<tr><td>▪ Sub-grade, including earthworks and ground works;
▪ Sub-base;
▪ Base, binder and surface or concrete slabs;
▪ Additional ancillary road elements (optional).</td><td>▪ Base, binder and surface or concrete slabs.</td></tr>
</table>
</td>
</tr>
</table>

29 Aggregates can encompass: i) natural aggregates (such as sand, gravel, crushed rocks), ii) recycled aggregates (such as materials from Construction & Demolition Waste) and iii) secondary aggregates (such as slag and ashes from industrial processes)

Verification:	Verification:
The design team or the DB tenderer or the DBO tenderer shall provide an estimate of the CO2e/tonne for aggregates that are used in the specified road elements using the calculation tool specified in the ITT. The transport mode(s) shall be specified and the emissions factor for each transport mode multiplied by the relevant quantities of materials as stated in the Bill of Quantities (BoQ).	The design team or the DB tenderer or the DBO tenderer shall provide an estimate of the CO2e/tonne for aggregates that are used in the specified road elements using the calculation tool specified in the ITT. The transport mode(s) shall be specified and the emissions factor for each transport mode multiplied by the relevant quantities of materials as stated in the Bill of Quantities (BoQ.)
CONTRACT PERFORMANCE CLAUSES	
Please refer to the general contract performance clause C1 Commissioning of road construction.	Please refer to the general contract performance clause C1 Commissioning of road construction.
Please refer to the general contract performance clause E4 Commissioning of road maintenance	Please refer to the general contract performance clause E4 Commissioning of road maintenance

Summary rationale for the final criteria proposal:

- If aggregates are moved over distances greater than 25 km, the resulting emissions can contribute significantly to the environmental impacts of the production phase for the main road elements.
- Transportation of aggregates is one of the main environmental hot spots for asphalt, concrete and (unbound) aggregates production but can vary depending on transport distances. Materials transport is often unique to the specific road construction projects. The contribution to cradle to gate Global Warming Potential (CO_2e) can indicatively range from 6% to 13-29% for asphalt, from 1.3% to 10% for concrete and from 50% to 66-89% for unbound aggregates used in the road base and sub-base.
- The mode of transport is a particularly important consideration. Transport of these materials is typically by lorry, which can be four times more carbon intensive than rail and thirty seven times more carbon intensive than bulk shipping. Minimising transport-related emissions can therefore help to promote the use of lower impact modes of transport such as rail or shipping for these materials.
- Materials transportation is already included in the holistic approach by means of the carbon footprint or the LCA. If points are not assigned by means of a CF or LCA, an alternative award criterion is proposed on the evaluation of the CO_2e emission / tonne of material transported.
- It is recommended combining this criterion with the criterion on recycled content in order to achieve an overall environmental benefit. This should always be done based on an understanding of the local market conditions (e.g. local recycling capacity, transport infrastructure) and by establishing and clearly specifying in the ITT a weighting of the two criteria that will ensure effective competition and reward bids that offer the best overall environmental performance.
- There are several nationally or internationally available GHG calculators that can be used to this purpose.

2.3.4.4 At what stage of the procurement process are the criteria relevant?

Firstly, it has to be underlined that integrated project delivery procurement systems and early contractor involvement (ECI) could provide early opportunities before fixing the alignment in the preliminary scoping and feasibility: Early use of contractor knowledge during the design can help minimise hauls, not just optimise hauls. Hampson *et al.*, (2012) case study demonstrated how ECI helped achieve total savings in fuel consumption of approximately 60% by optimizing the mass haul.

The evaluation of the CO_2e emissions from the transportation of materials for the main road elements has been proposed as an award criterion (both Core and Comprehensive criterion) to be applied during the detailed design and performance requirements procurement phase.

The criteria classification, their reference numbers in the criteria document and the respective procurement phase can be cross-referenced as follows.

Title of the criterion	Procurement phase	Criterion classification	Criteria typology	Reference number in the criteria document
Performance requirements for CO2e emissions from the transportation of aggregates	B. Detailed design and performance requirements	Core and Comprehensive	Award criterion	B16

2.3.5 Asphalt

2.3.5.1 Tar-containing asphalt

2.3.5.1.1 Background technical aspects, discussion and rationale for tar-containing asphalt

PAHs (Polycyclic Aromatic Hydrocarbons) are contaminants recognised to be carcinogenic, mutagenic, and teratogenic. In road pavements, tar-containing road materials could include PAHs (BIOIS, EC, 2011). Bituminous materials containing coal tar are included as hazardous waste in the European Waste Catalogue (EWC 17-03-01*). Limits are set by national environmental legislations (see examples in Table 16) and therefore the definition of tar-containing asphalt can differ from country to country.

Table 16: Limits for tar-containing (reclaimed) asphalt in different MSs.

Belgium	Sweden	The Netherlands
< 100 mg	< 70 ppm	< 75 ppm
PAH-10/kg	PAH-16 (approximate by the sum of PAH-L, PAH-M and PAH-H)	sum of 10-PAH

Analysing the tar content in reclaimed asphalt is relevant if coal tar has been used in the past. The age of roads that might contain tar can be different in different countries. For example, according to stakeholders, there could be a risk of tar-containing asphalt in roads built before 1974 in Sweden, 1992 in Flanders and 1985 in the UK. A stakeholder underlined that surface dressing using cutbacks containing aromatic oils, such as creosote, have been used fairly recently and will give a positive testing result for tar. Therefore it would be difficult to gauge road age, because any road surface dressed up to the mid '90s could have had tar/tar oils included in the cutback or emulsion. On the contrary, another stakeholder pointed put that the use of anthracene oil/creosote has been banned in Europe since 2003 and that in some MSs only emulsions are used.

Other stakeholders pointed out that it is difficult to set an age limit on roads and that is the responsibility of the road owner to ensure that the constituents of the pavement are known prior to removal of the old road surface, binder and base courses. This information should be collected by the contracting authority in inventories and databases. It was not considered practical that the contractor is required to test for tar-containing asphalt in the road. During the 2nd round consultation it has been pointed out that the possible tar content of surface layers (surface + binder courses) and base course layer(s) has usually to be tested by the contracting authority and the results of these tests has to be made available in the ITT. Typical procedures to analyse tar-containing asphalt are:

- Performing non-destructive tests as the simple UV-lamp onsite and "smell" test. The so-called Pak-Marker is used to screen the presence of tar and to detect PAH in asphalt products.
- Sampling (drilling) and performing chemical analysis by means of GCMS (gas chromatography mass spectrometry), HPLC (High-performance liquid chromatography) or thin layer chromatography.

Depending on the PAHs content, there are various methods for use/restrictions of tar-containing reclaimed asphalt and it has to be considered that different rules apply in different MSs. When milling existing asphalt layers, it is advisable to remove the tar-containing asphalt layer individually and keep it separate from the other layers. It shall not be used in the hot recycling in order to prevent PAHs emissions. Dutch legislation is forbidding recycling tar-containing asphalt already for a decade, and destruction by special incineration plants is required. In some countries, only cold recycling with or without binders (emulsion, foam bitumen and or hydraulic binders) is allowed. According to stakeholders, binding tar-containing reclaimed asphalt may be a possible sustainable way to treat and avoid leaching (Turk *et al.*, 2014). For example, in Sweden, only CMA or WMA/HWMA techniques are allowed in this case. It is suggested that the amount of tar-containing asphalt re-used in a specific place should be large enough (1500 m^3 in Flanders) to be able to map this presence and register in a database and not allow uncontrolled dilution.

Stakeholders suggested defining an upper threshold of tar content where the RAP could be re-used and encapsulated using a cold process off-site and, above this limit, then only on-site cold recycling should be used. The definition of this threshold appears related to the national legislation and therefore, it cannot be generalised and defined for the EU-28. Tar-containing asphalt is listed in the European Waste Catalogue as hazardous waste and therefore there are national-level legal requirements in place regarding its use, ownership and shipment.

The aim of this criterion is to encourage best practices, which could be more ambitious than the legal requirements, which may simply be landfilling. It has to be underlined that in some MSs best practices already apply and there is no added-value in including this criterion in the ITT. However, as highlighted in the 2nd AHWG, for some MSs the inclusion of this criterion in an ITT would be beneficial in order to implement best available techniques to treat reclaimed asphalt containing tar. Monitoring during construction is important and a system to account for tar-containing reclaimed asphalt and to track shipments to off-site destinations or on-site re-use has been specified in the verification.

2.3.5.1.2 Final criteria proposal

Core criteria	**Comprehensive criteria**
TECHNICAL SPECIFICATIONS	
E1. Tar-containing asphalt *(The contracting authority may apply this criterion if tar content of surface layers (surface + binder courses) and base course layer(s) exceeds the limit set by the national legislation)* If the tar content of the to-be-reclaimed asphalt exceeds the limit set by the national legislation, best available techniques (*according to what is considered as best available techniques in each MS with reference to the local situation)* to treat the reclaimed asphalt containing tar shall be applied and their application shall be described in a technical report. **Verification:** The main construction contractor *or* the DB contractor *or* the DBO contractor shall submit a technical report consisting of best available techniques to treat the reclaimed asphalt containing tar through cold mixing on site and/or off-site options. A system shall be used to monitor and account for tar-containing reclaimed asphalt and to track off site destination and on site re-use, specifying amount of materials and identifying the location (maps, GIS). Monitoring data shall be provided to the contracting authority.	**E1. Tar-containing asphalt** *(The contracting authority may apply this criterion if tar content of surface layers (surface + binder courses) and base course layer(s) exceeds the limit set by the national legislation)* If the tar content of the to-be-reclaimed asphalt exceeds the limit set by the national legislation, best available techniques (*according to what is considered as best available techniques in each MS with reference to the local situation)* to treat the reclaimed asphalt containing tar shall be applied and their application shall be described in a technical report. **Verification:** The main construction contractor *or* the DB contractor *or* the DBO contractor shall submit a technical report consisting of best available techniques to treat reclaimed asphalt containing tar through cold mixing on site and/or off-site options. A system shall be used to monitor and account for tar-containing reclaimed asphalt and to track off site destination and on site re-use, specifying amount of materials and identifying the location (maps, GIS). Monitoring data shall be provided to the contracting authority.

Summary rationale for the final criteria proposal:

- Analysing the tar content in reclaimed asphalt is relevant if coal tar has been used in the past. The age of roads that might contain tar can be different in different countries. Doing this is the task of the contracting authority before launching the ITT.
- Depending on the PAHs content, there are various methods to treat and restrictions for use of tar-containing reclaimed asphalt.
- If the tar content of reclaimed asphalt exceeds the limit set by national legislation, best available techniques to treat or, eventually, use reclaimed asphalt containing tar shall be specified in a technical report. A system to monitor and account for the tar-containing reclaimed asphalt is also proposed.

2.3.5.2 Low temperature asphalt

2.3.5.2.1 Background technical aspects, discussion and rationale for low temperature asphalt

Traditionally, asphalt is referred to what is known as a "hot mix" process, the product being referred to as **HMA** (140-190°C). Where asphalt is specified in road construction, there exist a number of possibilities to reduce the environmental impact associated with its production. This can be done by using a lower temperature mixing process such as **WMA** (100-140°C), **HWMA** (70-100°C) or **CMA** (<60°C) (EAPA, 2007; D'Angelo *et al.*, 2008; EAPA, 2010; Capitão *et al.*, 2012; Rubio *et al.*, 2012; Blankendaal *et al.*, 2014). Stakeholders have indicated that experiences (both in Europe and USA) from the last 5-10 years suggest that WMA/HWMA have equivalent performances of HMA. CMA is a different mix type, thus there are situations where its use is not equivalent to the others.

As suggested by stakeholders, the overall environmental benefits of using low temperature asphalt are now included in the CF/LCA performance requirements. As underlined in section 2.3.2, several tools allow evaluating energy consumption and carbon footprint of construction materials, including asphalt, during construction and maintenance phases. The contractor can choose between the use of HMA/WMA/HWMA/CMA considering the specific requirements and conditions of the project.

Not only do lower temperature mixing processes save energy, they have been associated with significantly lower VOC, PAH, CO, SO_2 and NO_x emissions, which is important both from an occupational **health and safety** and an environmental point of view (EAPA, 2010; D'Angelo *et al.*, 2008; Wayman *et al.*, 2012). It has however to be considered, as it has been underlined during the 2nd AHWG and the 2nd round consultation, that occupational health and safety are covered by separate EU legislation national regulations.

A WMA Task Force established by the Flemish Road authority has recently concluded that both a minimum and maximum temperature has to be declared by the contractor for a given asphalt mixture and WMA technology. A stakeholder pointed out that it is important to be aware of the lower temperature limit at which the subsequent compaction can be carried out without compromising the asphalt mixture durability. The declared minimum temperature corresponds to the temperature at which the initial type testing has to be carried out. Having these limitations, contractors are aware that, in case of WMA use, the compaction window can be smaller than in case of HMA use, with the consequent risk of a reduced workability. The technical issues related to the use of WMA technologies such as ITT study (including temperature windows for the WMA asphalt) has been specified in the tender specifications[30] of the Flemish Road authority. In the draft Italian GPP criteria, maximum temperatures for laying the bituminous mixtures of the surface and binder courses are proposed. The Andalusian Road Authority proposed technical specifications for low temperature asphalt (<100° C) produced by means of bituminous emulsions in ITT for low traffic roads (AOJPA, 2012). However, there are some examples of HWMA and CMA used in higher traffic roads (ATEB, 2014).

High temperatures should be allowed in cases of specific high-performance bituminous mixtures realised with specific binders with higher viscosities, for example in rubberised asphalt pavement. However, it can be observed that at around 160° C, differences in viscosity between the bituminous mixtures with different pulverised rubber contents are decreasing and a higher temperature would only still be required with 20% of pulverised rubber asphalt would a higher temperature still be required (Santagata *et al.*, 2012 and Ecopneus), as it is shown in Figure 22.

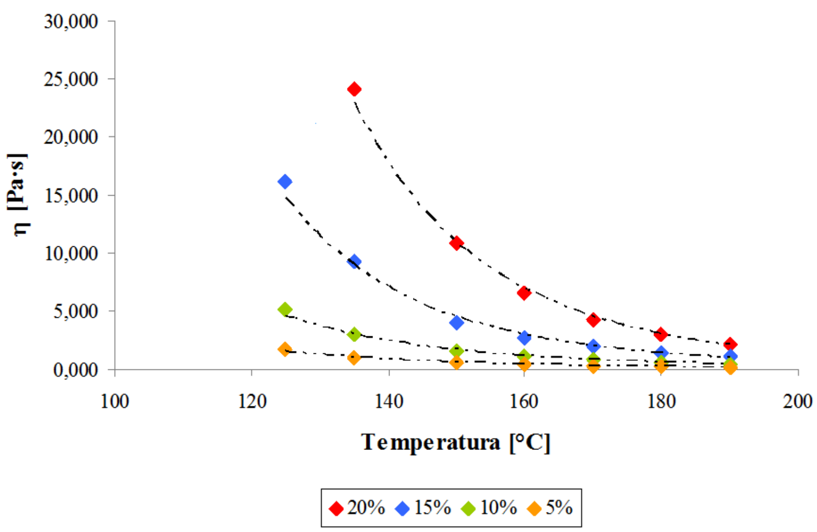


Figure 22: Relationship between rubberised asphalt viscosity and temperature (Ecopneus).

30 Agentschap Wegen en Verkeer http://wegenenverkeer.be/sites/awv/files/docs/Hoofdstuk06%20%281%29.pdf

In conclusion, mixing and laying techniques that decrease the asphalt production and laying temperature should be used. For this reason, a technical specification is proposed for both Core and Comprehensive criteria as following: the maximum temperature for laying the bituminous mixtures of the surface and binder courses shall not exceed 140°C in the Core criterion and 120°C in the Comprehensive criterion. Only in case of specific performance bituminous mixtures (such as rubberised asphalt, High Modulus Asphalt or Polymer Modified Bitumen PmB, *etc.*), realised with special binders with the purpose of decreasing noise, of using less materials for the same structural value or of having benefits on long-term basis with less maintenance needed over a cycle time, will the laying temperature be allowed to exceed these values. In those later cases, laying temperature shall be lower than 155° C.

It has to be underlined that overall environmental benefits of using low temperature asphalt are included in the CF/LCA performance requirements. Therefore, it appears more straightforward to propose a technical specification setting maximum temperature values for the laying the bituminous mixtures.

2.3.5.2.2 Final criteria proposal

Core criteria	**Comprehensive criteria**
TECHNICAL SPECIFICATIONS	
B1. Low temperature asphalt The design team *or the* DB tenderer *or* the DBO tenderer shall apply best practice and techniques for laying bituminous mixtures in order to lower the asphalt production and application temperature. The maximum temperature for laying the bituminous mixtures of surface and binder courses shall not exceed 140°C. Only in cases of higher viscosity special bituminous mixtures, laying temperatures up to greater than 140°C, but lower than 155°C, shall be allowed. **Verification:** The design team *or* DB tenderer *or* the DBO tenderer shall provide a technical report and a workplan of the design activities, indicating the mixing and laying techniques and the maximum temperatures required by these techniques, including technical data sheets on binder formulation and asphalt mix design provided by the producer(s).	**B1. Low temperature asphalt** The design team *or the* DB tenderer *or* the DBO tenderer shall apply best practice and techniques for laying bituminous mixtures in order to lower the asphalt production and application temperature. The maximum temperature for laying the bituminous mixtures of surface and binder courses shall not exceed 120°C. Only in cases of higher viscosity special bituminous mixtures, laying temperatures up to greater than 120°C, but lower than 155°C, shall be allowed. **Verification:** The design team *or* DB tenderer *or* the DBO tenderer shall provide a technical report and a workplan of the design activities, indicating the mixing and laying techniques and the maximum temperatures required by these techniques, including technical data sheets on binder formulation and asphalt mix design provided by the producer(s).
CONTRACT PERFORMANCE CLAUSES	
C4. Monitoring of the low temperature asphalt The laying temperature of the low temperature asphalt shall be verified for each batch[31] of product at the worksite. The main construction contractor *or* the DB contractor *or* the DBO contractor shall provide either: - an independent laboratory certification of the maximum laying temperature of the asphalt; - *or* equivalent documentation provided by asphalt producer(s).	**C4. Monitoring of the low temperature asphalt** The laying temperature of the low temperature asphalt shall be verified for each batch[29] of product at the worksite. The main construction contractor *or* the DB contractor *or* the DBO contractor shall provide either: - an independent laboratory certification of the maximum laying temperature of the asphalt; - *or* equivalent documentation provided by asphalt producer(s).
E6. Monitoring of the low temperature asphalt *The same as C4.*	**E6. Monitoring of the low temperature asphalt** *The same as C4.*

Summary rationale for the final criteria proposal:

- The proposed criterion doesn't identify a preferred technique among WMA, HWMA and CMA, whose use depends on the specific requirements and conditions of the project. The overall environmental benefits of using low temperature asphalt are included in the holistic CF/LCA performance approach.

31 "Batch" means a quantity of uniformly labelled product manufactured by the same mixing plant, under the same conditions according to a set mix design with the same input materials.

- Technical issues related to the use of WMA have been specified in the tender specifications of the Flemish authority for public procurement. In the draft Italian GPP criteria, maximum temperatures for laying the bituminous mixtures of the surface and binder courses are proposed.
- Mixing and laying techniques that decrease the asphalt temperature should be used. For this reason a technical specification is proposed for both Core and Comprehensive criteria as follows: the maximum temperature for laying the bituminous mixtures shall not exceed 140°C as Core criterion and 120°C as Comprehensive criterion. Only in case of specific performance bituminous mixtures realized with special binders, shall laying temperature be allowed to exceed these values while being lower than 155°C.

2.3.5.3 At what stage of the procurement process are the criteria relevant?

The criteria classification, their reference numbers in the criteria document and the respective procurement phase can be cross-referenced as follows.

Title of the criterion	Procurement phase	Criterion classification	Criteria typology	Reference number in the criteria document
Tar-containing asphalt	E. Maintenance and operation	Core and Comprehensive	Technical specification	E1
Low temperature asphalt	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B1
Monitoring of the low temperature asphalt	C. Construction	Core and Comprehensive	Contract performance clauses	C4
Monitoring of the low temperature asphalt	E. Maintenance and operation	Core and Comprehensive	Contract performance clauses	E6

2.3.6 Excavated materials and soils management and waste management

Large amounts of materials are excavated, re-used on-site and/or delivered off-site in recycling facilities. All these stages imply a range of significant environmental impacts due to the substantial amount of materials involved. A recent assessment of scenarios for resource efficiency for the European Resource Efficiency Platform of the Commission (EC, 2014) pointed out the importance of:

- Recycling and re-use of concrete and excavated materials instead of landfilling;
- Recycling of C&DW;
- Reducing in the amount of waste from construction.

ENCODE, whose members include a range of EU construction companies, proposed a construction and demolition waste measurement protocol which recommends recording separately construction, demolition and excavation waste production (ENCODE, 2013). In particular, the identified key performance indicators are:

- Total waste arising (t);
- Total waste recovery/recycling and re-use, evaluated as the % of all construction, demolition and excavation waste diverted from landfill/incineration without energy recovery (%);
- Optional indicators are for example the quantity of waste materials (excluded from WFD) a) recovered and re-used on-site and b) recovered on-site and sent off-site as materials/by product (t).

2.3.6.1 Excavated materials and soil management plan

2.3.6.1.1 Background technical aspects, discussion and rationale for excavated materials and soil management plan

Excavated materials could be classified as by-products (according to art. 5 of the WFD, and Italian legislation n. 161, 10.08.2012) or re-used, recycled or recovered materials according to the WFD hierarchy (see, for example, ENCODE’ Appendix 2, 2013). Hazardous excavated waste shall be identified separately and managed according to the WFD and national legislations. Excavation waste are unwanted material resulting from excavation activities such as a reduced level dig and site preparation and levelling, and the excavation of foundations, basements and trenches, typically consisting of soils and stones (ENCODE, 2013). Data from BIOIS (BIOIS, EC, 2011) reveals that the production of excavation waste (1350-2900 Mt/y) is significantly larger than what is defined as C&DW (341-531 Mt/y). According to Mália *et al.* (2013), excavated soils comprise a high percentage of C&DW but are usually not included in the waste management statistics.

Soils (topsoil and subsoil) are part of excavated materials. Soil is a vulnerable and essentially non-renewable resource. Some of the most significant impacts on soil properties occur as a result of construction activities (DEFRA, 2009). The re-use of soil is a strategic factor in the Waste Framework Directive WFD 2008/98/EC. According to article 2c):

> *"uncontaminated soil and other naturally occurring material excavated in the course of construction activities where it is certain that the material will be used for the purposes of construction in its natural state on the site from which it was excavated..."*

are excluded from the scope of the Directive. In greenfield construction sites, valuable topsoil should be managed separately and reincorporated into the site if possible or into other sites. All of the aforementioned aspects should be covered in a soil management plan for the project.

The LCA literature review shows that, in complex orography conditions, when embankments and ground works are needed, the impacts related to earthworks can account for the main percentage of total emissions during construction (Barandica *et al.*, 2013) and account for up to 30% of the project's emissions (Hampson *et al.*, 2012). From a GPP criteria development perspective, the information in this section highlights the potential importance of planning a closed-loop re-use of soils, particularly within the same worksite. In situations where soils are unsuitable as sub-grade material, relative environmental impacts and economic costs of soil excavation and replacement versus in-situ lime/cement stabilisation must be considered (Mroueh *et al.*, 2000). Regarding stabilizations, a stakeholder specified that stabilization with Portland cement and with lime have different objectives and they cannot be prioritized just for their impacts. Solutions with different functional purposes cannot be compared. Some tools, such as Geokalkyl, have been developed in order to estimate cost, energy and CO_2 emissions due to earthworks and geotechnical stabilization. These tools are used in the planning phase.

Environmental impacts of earthworks and ground works are already evaluated by means of the holistic LCA performance criteria proposed in section 2.3.2. The proposed criterion on excavated materials and soil aims at optimizing their management based on best practise and identifying key performance indicators such as the % of all materials diverted from landfill, % recycled or re-used materials on site, % recycled or re-used materials off-site. The maximum amount of excavation materials to be re-used on site in a close loop should be evaluated by means of a carbon footprint or LCA (see section 2.3.2).

Following the Code of practice on soil management of DEFRA (2009), the presentation of a soil management plan by the design team is proposed as a technical specification, for both core and comprehensive criteria. This should include:

- a soil resource survey, separate from the geotechnical and geo-environmental survey, prior to any earthworks, in order to quantify and characterise topsoil and subsoil;
- estimates of the total amount of excavated materials and topsoil, of the % of excavation materials diverted from landfill, of the % of re-use potential on site and of the % re-use and recycling potential off site;
- in greenfield, the separate management of topsoil and its reincorporation into the site or other sites where relevant, including:
    - maps of soil to be protected from earthworks and construction activities;
    - maps, types and volume of topsoil and subsoil to be stripped and stockpile locations;
    - methods for stripping, stockpiling, re-spreading and ameliorating the soils;
    - expected after-use for each soil, whether it is topsoil to be used on site (trying to keep soil storage periods as short as possible with adequate drainage system), used or sold off site, or subsoil to be retained for landscape areas, used as structural fill or for topsoil manufacture.

The application of the DEFRA Code of Practice guarantees the implementation of minimum strategies for preserving the topsoil quality. A stakeholder underlined that soil management plans are mandatory in construction projects. However it has to be considered that these plans are usually quite generic and do not specifically deal with best practices. On the contrary, the performance requirements proposed, such as the estimations of materials diverted from landfill, the % re-used and recycled on-site and off-site, and the best practices for topsoil, stimulate the application of best practices in all road projects. During the 2nd round of consultation, one stakeholder highlighted that an excavated material and soil management plan is normally developed by the contractor during the bidding process as basis for its pricing. It is perfectly normal that during the execution of such management plans, amendments are required due to differing material availability, differing land topography from design assumptions *etc*... For this reason it has been included in the contract performance clause that significant deviations from the excavated material and soil management plan must be discussed with the contracting authority, considering unforeseen project specific circumstances that may lead to additional constraints or potential improvements.

2.3.6.1.2 Final criteria proposal

<table>
<tr><th>Core criteria</th><th>Comprehensive criteria</th></tr>
<tr><td colspan="2">TECHNICAL SPECIFICATIONS</td></tr>
<tr><td>B2. Excavated Materials and Soil Management Plan

Waste production during excavation, excluding construction and demolition waste, shall be recorded.

An Excavation Materials and Soil Management Plan shall be prepared establishing systems for the separate collection of:

(i) excavated materials resulting from excavation activities (for example from site preparation and levelling, foundation, basement and trench excavation), typically soil and stones, including subsoil;
(ii) topsoil.

Closed loop re-use on-site for both excavated materials and topsoil should be maximised according to the results of the carbon footprint or LCA performance assessment (see criterion B14).

Separate excavated material collection for re-use, recycling and recovery shall respect the waste hierarchy in Directive 2008/98/EC.

Verification:

The design team or the DB tenderer or the DBO tenderer shall provide a extracted materials and topsoil management plan consisting of:

(i) A bill of quantities with estimates for excavated materials based on good practices, as defined in the Code of practice on soil management of DEFRA (2009) and/or in the ENCODE Protocol (2013);
(ii) Estimates of all materials diverted from landfill and identification of potential hazardous substances;
(iii) Estimates of the % by weight re-used and/or recycled materials on site;
(iv) Estimates of the % by weight re-used and/or recycled materials off site;
(v) Total amount of topsoil and strategies to preserve its quality.</td><td>B2. Excavated Materials and Soil Management Plan

Waste production during excavation, excluding construction and demolition waste, shall be recorded.

An Excavation Materials and Soil Management Plan shall be prepared establishing systems for the separate collection of:

(i) excavated materials resulting from excavation activities (for example from site preparation and levelling, foundation, basement and trench excavation), typically soil and stones, including subsoil;
(ii) topsoil.

Closed loop re-use on-site for both excavated materials and topsoil should be maximised according to the results of the carbon footprint or LCA performance assessment (see criterion B14).

Separate excavated material collection for re-use, recycling and recovery shall respect the waste hierarchy in Directive 2008/98/EC.

Verification:

The design team or the DB tenderer or the DBO tenderer shall provide a extracted materials and topsoil management plan consisting of:

(i) A bill of quantities with estimates for excavated materials based on good practices as defined in the Code of practice on soil management of DEFRA (2009) and/or in the ENCODE Protocol (2013);
(ii) Estimates of all materials diverted from landfill and identification of potential hazardous substances;
(iii) Estimates of the % by weight re-used and/or recycled materials on site;
(iv) Estimates of the % by weight re-used and/or recycled materials off site;
(v) Total amount of topsoil and strategies to preserve its quality.</td></tr>
<tr><td colspan="2">CONTRACT PERFORMANCE CLAUSES</td></tr>
<tr><td>C5. Commissioning of the Excavated Materials and Soil Management Plan

The main construction contractor or DB contractor or DBO contractor shall implement a system to monitor and report on actions involving excavated materials and soil during the</td><td>C5. Commissioning of the Excavated Materials and Soil Management Plan

The main construction contractor or DB contractor or DBO contractor shall implement a system to monitor and report on actions involving excavated materials and soil during the</td></tr>
</table>

progress of construction work on-site. This system shall include data accounting for the weights generated (topsoil and excavated materials), the percentages re-used/recycled on site and percentages re-used and/or recycled off site. It shall also track and verify the destination of consignments of excavated materials. The monitoring and tracking data shall be provided to the contracting authority on an agreed periodic basis. The main construction contractor or the DB contractor or the DBO contractor shall, in cases where a significant deviation from the excavated materials and soil management plan proposed in the design phase is considered necessary, inform the contracting authority and agree, if justified, upon any deviation.	progress of construction work on-site. This system shall include data accounting for the weights generated (topsoil and excavated materials), the percentages re-used/recycled on site and percentages re-used and/or recycled off site. It shall also track and verify the destination of consignments of excavated materials. The monitoring and tracking data shall be provided to the contracting authority on an agreed periodic basis. The main construction contractor or the DB contractor or the DBO contractor shall, in cases where a significant deviation from the excavated materials and soil management plan proposed in the design phase is considered necessary, inform the contracting authority and agree, if justified, upon any deviation.

Summary rationale for the final criteria proposal:

- The LCA literature review shows that, in complex orography conditions, when embankments and ground works are needed, the impacts related to earthworks can account for the main part of total emissions during construction and account for up to 30% of the project. It is proposed that environmental impacts of earthworks and ground works are to be evaluated by means of the holistic LCA performance criteria proposed in section 2.3.2.
- The preparation of an Excavated Materials and Soil Management Plan, including optimization and best practices, is proposed as a technical specification. Estimates of the total amount of excavated materials and topsoil, of the % of excavation materials diverted from landfill, of the % of re-use potential on-site and of the % re-use/recycling potential off-site shall be included. In greenfield, the separate management of topsoil and its reincorporation into the site or other sites where relevant, should be proposed.

2.3.6.2 Demolition Waste Management Plan

2.3.6.2.1 Background technical aspects, discussion and rationale for Demolition Waste Management Plan

The importance of waste management is reflected in the development of the WFD. Article 11.2 is of particular relevance to the construction sector, stating that:

> *"(b) by 2020, the preparing for re-use, recycling and other material recovery, including backfilling operations using waste to substitute other materials, of non-hazardous construction and demolition waste* (C&DW) *excluding naturally occurring material defined in category 17 05 04 in the list of waste shall be increased to a minimum of 70 % by weight."*

C&DW has been identified as a priority waste stream by the European Union because of its high potential for recycling and re-use. The existing level of recycling and re-use of C&DW varies greatly (between less than 10% and over 90%) in the Member States (EC, 2014; WBCSD, 2009). BIOIS, EC (2011) has estimated the average recycling percentage at 46% across the EU. According to Mália *et al.* (2013), Denmark and the Netherlands have already been achieving recycling rates above 90% of C&DW for a decade. 65% and 85% of C&DW produced respectively in UK and Germany are either re-used or recycled. According to this estimate, in Spain and Portugal, this ratio is still lower than 30%. However, it has to be noted that there are considerable doubts about the reliability of official statistics.

According to WRAP's Guidance on procurement requirements for reducing waste and using resources efficiently, it is recommended that a Demolition Waste Management Plan is developed including project-specific targets for total waste arisings and the amount of waste sent to landfill. The purpose of the Waste Management Plan is to ensure, firstly, a reduction of the C&DW generation and, secondly, a suitable treatment of the unavoidable C&DW generated to ensure that it causes the lowest environmental impact.

According to both the scientific literature and experience from Member States, a pre-demolition audit allows for identification of the key infrastructure materials, which will arise from maintenance and rehabilitation activities and road decommissioning. The typical information provided by the audit comprises:

- Identification and risk assessment of hazardous waste that may require specialist handling and treatment, or emissions that may arise during demolition;
- A Demolition Bill of Quantities (BoQ) with a breakdown of different construction materials;
- An estimate of the % re-use and recycling potential during the demolition process;
- An estimation of the % potential for other forms of recovery from the demolition process.

According to BIOIS, EC (2011), off-site RAP recycling in stationary plants could absorb between 30 to 80% of RAP, while on-site recycling could absorb 100% of RAP. Concrete recycling into aggregates for road construction and backfilling could absorb up to 75% of waste concrete, while recycling into aggregates for concrete production could absorb 40-50%.

According to WRAP's Guidance, ENCODE (2013) and the ICE Demolition Protocol (2008), a specific target of at least 80% of C&D waste to be re-used, recycled and recovered can be established. This reflects a higher band of best practice in some Member States as identified by BIOIS, EC (2011). In the draft Italian GPP criteria, award points are proposed if at least 50% of C&D waste from surface and binder courses is re-used/recycled in new pavements, 80% of RAP is re-used in surface and binder base course and cannot be employed in road-base and sub-base, 30% from the C&D waste of existing building and infrastructure is used in the sub-base.

It is therefore proposed that the non-hazardous waste generated during demolition of any bound and/or unbound materials of the pavement layers and ancillary materials are prepared for re-use, recycling and other forms of material recovery. Backfilling operations are not to be taken into consideration according to the best practices described within the EC EMAS Reference Document on Best Environmental Management Practice in the building and construction sector (EC, JRC, 2012a). However, this exclusion is more appropriate for the building sector. In the road sector, it is suggested to include backfilling, even though it can be classified as downcycling, taking into consideration the common practices of cut and fill, environmental rehabilitation and landscape creation. Backfilling should not be allowed in greenfield outside of the roadway. Moreover, backfilling in permeable areas of the roadway (for example shoulders and embankments) should be realised only with (non-hazardous) excavated materials and soils, while other re-used, recycled and recovered materials (for example RAP, crushed concrete, *etc.*) should be used for backfilling only in impermeable areas of the roadway. During the 2nd AHWG meeting further limitations regarding backfilling conditions, such as the definition a maximum percentage of backfilling that can be accounted as a recovery operation, and regarding leaching limits set by national legislation in specific situations, have not been required. However, during the 2nd round of consultation, a stakeholder underlined that backfilling should not be allowed for unprocessed waste and this has been pointed out in the criteria proposal.

Therefore, the specific target established in the WFD to re-use, recycle or materially recover a minimum of 70% by weight, including backfilling, is proposed as Core GPP criterion. The specific target of at least 90% by weight could be proposed as a Comprehensive GPP criterion, but potentially only for use in those Member States where this represents best practice and for materials to be prepared for re-use and recycling rather than recovery, in order to stimulate innovations in line with the waste hierarchy.

The materials, products and elements identified shall be itemised in a Demolition Bill of Quantities. Material segregation and recovery shall respect the waste hierarchy in Directive 2008/98/EC.

2.3.6.2.2 Final criteria proposal

Core criteria	**Comprehensive criteria**
TECHNICAL SPECIFICATIONS	
E2. Demolition Waste Audit and Management Plan A minimum of 70% by weight of the non-hazardous waste generated during demolition, including backfilling, shall be prepared for re-use, recycling and other forms of material recovery. This shall include: (i) Concrete, RAP, aggregates recovered from the main road elements; (ii) Materials recovered from ancillary elements. Backfilling shall not be allowed in greenfield sites outside the roadway. Backfilling in permeable areas of the	**E2. Demolition Waste Audit and Management Plan** A minimum of 90% by weight of the non-hazardous waste generated during demolition, including backfilling, shall be prepared for re-use, recycling and other forms of material recovery. This shall include: (i) Concrete, RAP, aggregates recovered from the main road elements; (ii) Materials recovered from ancillary elements. Backfilling shall not be allowed in greenfield sites outside the roadway. Backfilling in permeable areas of the

roadway shall be realised only with excavated materials and soils. Re-used, recycled and recovered materials shall only be used for backfilling in impermeable areas of the roadway. The main construction contractor *or* the DB contractor *or* the DBO contractor shall carry out a pre-demolition audit in order to determine what can be re-used, recycled or recovered. This shall comprise: (i) Identification and risk assessment of hazardous waste; (ii) A bill of quantities with a breakdown of different road materials; (iii) An estimate of the % re-use and recycling potential based on proposals for systems of separate collection during the demolition process. The materials, products and elements identified shall be itemised in a Demolition Bill of Quantities. **Verification:** The main construction contractor *or* the DB contractor *or* the DBO contractor shall submit a pre-demolition audit that contains the specified information. A system shall be implemented to monitor and account for waste production. The destination of consignments of waste and end-of-waste materials shall be tracked using consignment notes and invoices. Monitoring data shall be provided to the contracting authority.	roadway shall be realised only with excavated materials and soils. Re-used, recycled and recovered materials shall only be used for backfilling in impermeable areas of the roadway. The main construction contractor *or* the DB contractor *or* the DBO contractor shall carry out a pre-demolition audit in order to determine what can be re-used, recycled or recovered. This shall comprise: (i) Identification and risk assessment of hazardous waste; (ii) A bill of quantities with a breakdown of different road materials; (iii) An estimate of the % re-use and recycling potential based on proposals for systems of separate collection during the demolition process. The materials, products and elements identified shall be itemised in a Demolition Bill of Quantities. **Verification:** The main construction contractor *or* the DB contractor *or* the DBO contractor shall submit a pre-demolition audit that contains the specified information. A system shall be implemented to monitor and account for waste production. The destination of consignments of waste and end-of-waste materials shall be tracked using consignment notes and invoices. Monitoring data shall be provided to the contracting authority.
F1. Demolition waste audit and management plan *The same as E2.*	**F1. Demolition waste audit and management plan** *The same as E2.*

Summary rationale for the final criteria proposal:

- The importance of waste management is reflected in the Waste Framework Directive, in which C&DW has been identified as a priority waste stream because of its high potential for recycling and re-use. A minimum recycling target of 70% for re-use, recycling and other material recovery of C&D waste by 2020 is fixed by the WFD. Sectoral studies estimate an average percentage of 46% of recycling and re-use of C&DW across the EU.
- It is recommended that a Demolition Waste Management Plan is developed including project-specific targets for total waste production and the amount of waste sent to landfill. A pre-demolition audit allows for identification of hazardous waste and their and risk assessment, a Demolition Bill of Quantities, estimates of the % re-use and recycling potential and of the % potential for other forms of recovery during the demolition process.
- Off-site RAP recycling in stationary plants can absorb between 30 to 80% of RAP, while 100% on-site recycling of RAP is achievable. Concrete recycling into aggregates for road construction and backfilling could absorb up to 75% of waste concrete, while 40-50% of waste concrete might be recycled to produce aggregates for concrete production.
- It is therefore proposed that the non-hazardous waste generated during demolition of any bound and/or unbound materials of the pavement layers and ancillary materials are prepared for re-use, recycling and other forms of material recovery. It is suggested to include backfilling operation, even though it can be classified as down-cycling, taking into consideration the common practices of cut-and-fill, environmental rehabilitation and landscape creation. Specific targets of a minimum of 70% by weight, including backfilling, is proposed as Core criterion, and of at least 90% by weight as a Comprehensive criterion.

2.3.6.3 At what stage of the procurement process are the criteria relevant?

It has to be underlined that, in order to fully benefit from waste reduction and recovery on a project, good practices must be adopted at the earliest possible stage, and planned actions, metrics and targeted outcomes must be communicated between the contracting authority and tenderers and passed down through the supply chain (including the design teams, subcontractors, waste management contractors and material suppliers) and across all project phases in the preliminary scoping and feasibility. In soil management ECI (early contractor involvement) is important in order to optimise the decision on road alignment and subsequent consequences regarding the amount of excavated soil.

Waste management planning has been split into a Demolition Waste Management Plan and an Excavated Materials and Soils Management Plan, proposed as technical specifications (both in Core and Comprehensive criteria) in the design phase and performance requirements. The criteria on the soil and excavation waste management should be applied during the detailed design phase: the design team or the DB tenderer or the DBO tenderer shall quantify the maximum amount of re-used soils within the soil management plan and the management activities on the reserves of topsoil and subsoil. Monitoring of the soil management plan via site inspections shall be demonstrated in the construction phase.

With reference to the Demolition Waste Management Plan, the main *construction contractor* or the *DB contractor or* the *DBO contractor* shall carry out and submit a pre-demolition audit that contains the specified information on what can be re-used, recycled and submit the site waste management plan in the maintenance and EoL phases. For both criteria, waste productions shall be accounted for and monitored, including information on the transportation distances of waste and end-of-waste materials (only in the case of the Demolition Waste Management Plan) using consignment notes and invoices. Monitoring data shall be provided to the contracting authority.

The criteria classification, their reference numbers in the criteria document and the respective procurement phase can be cross-referenced as follows.

Title of the criterion	**Procurement phase**	**Criterion classification**	**Criteria typology**	**Reference number in the criteria document**
Excavated Materials and Soil Management Plan	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B2.
Commissioning of the Excavated Materials and Soil Management Plan	C. Construction	Core and Comprehensive	Contract performance clause	C5
Demolition Waste Audit and Management Plan	E. Maintenance and operation - F. End of Life	Core and Comprehensive	Technical specifications	E2 – F1.

2.4 Water and habitat conservation

2.4.1 Background technical aspects, discussion and rationale for water and habitat conservation

Technical aspects of particular relevance

Road drainage systems must comply with minimum technical requirements in order to adequately drain both stormwater from the road surface and sub-surface water from groundwater flows that may impact on the sub-base. The drainage system design must take into account factors and coefficients related to pipe diameters, slopes and local rainfall data. The optimum drainage system design will always be tailored specifically to each site. Consequently, it is considered that such a technical level of detail would not be appropriate for general GPP criteria.

Nonetheless, once the basic technical requirements of the drainage system are optimised, a variety of drainage structures, with varying degrees of environmental credentials, may be considered and therefore are relevant to GPP criteria.

Drainage systems have the potential to foster habitat creation and/or enhance existing habitat. An important impact of road construction is habitat destruction and fragmentation and this is especially relevant in rural areas and areas of high ecological value. The optimum road path from a technical and economic point of view, and even from specific environmental perspectives such as earthworks or road distance, may result in the route passing through a particular area of high ecological value.

The following impacts which affect water and habitat conservation should be considered:

- the transfer of pollutants to local watercourses during road construction;
- the transfer of pollutants to local watercourses during the use phase of the road;
- the contribution of road surfaces and drainage to local and downstream flooding during the use phase of the road;
- habitat destruction caused by road construction;
- habitat fragmentation caused by road construction and use;
- risks to flora and fauna caused during the use phase of the road.

More detailed information on technical examples and technical aspects of the above listed points can be found in Annex 5.

Discussion and rationale for criteria proposal

The discussion during the 2nd AHWG meeting and feedback received since then was relatively limited. One stakeholder mentioned the UK Design Manual for Roads and Bridges (DMRB) Volume 11, Section 3-Part 10 (HD 45/09) "Road drainage and the water environment" which addresses both risks due to water pollution and flooding. Regarding water pollution, a general requirement is that road drainage shall not result in a deterioration of the classification of nearby surface or groundwater bodies as per the Water Framework Directive (2000/60/EC). For flooding it is stated that road structures must not result in a net loss of floodplain storage, not impede water flows and not increase flood risk elsewhere. A series of tools and guidance are provided, including the Highways Authority Water Risk Assessment Tool (HAWRAT) for watercourse pollution sensitivity and the Highways Authority Drainage Data Management System (HADDMS) for assessing the local flood risks.

Regarding drainage systems, it was mentioned that the Dutch approach for modelling and sizing of road drainage systems is much stricter if there is less free space around the road, which is reflected in their design storm specifications below:

- For roads with ample space: a 1 in 10 year storm of 2 hours duration (+30% climate change factor);
- For roads with little space: a 1 in 50 year storm of 2 hours duration (+30% climate change factor);
- For roads with no space (*i.e.*, tunnels and parts of city centres): a 1 in 250 year storm of 2 hours duration (+30% climate change factor).

Regarding sediment removal performance, it was commented that this was difficult to quantify and specific requirements should be avoided. Instead, criteria should be set in way in which "soft engineered" solutions are favourably weighted compared to more traditional alternatives – be that for sediment removal, flood risk minimisation or the provision of wildlife corridors. With regards to monitoring of the drainage system, the importance of observation during construction (as it is often the only chance to see the full system before parts of it are buried) and during routine maintenance was emphasised.

After the meeting, written comments were submitted by two stakeholders in relation to ecological aspects of the road construction project. The first set of comments was focussed on broader issues such as land use and fragmentation, species migration and habitat loss. A general reference to Swedish guidance documents for road design and preventing habitat damage[32] as well as the COST 341 report was made.

The second set of comments focussed on specific measures that can be introduced in GPP criteria including roadside vegetation, ornamental planting and vegetation contained in stormwater facilities.

The potential environmental benefits of criteria related to water and habitat conservation will vary significantly depending on the nature and of the land surrounding the road. Where a potential to protect watercourses, decrease flood-risk or enhance local habitat for flora and fauna can be identified, tenderers should be encouraged to incorporate such aspects in their designs. Such approaches will most likely introduce an additional cost element during construction and so should be compensated for by award criteria.

All across Europe mains sewers are struggling with capacity in urban areas where they are combined with stormwater drains. A technical specification is therefore proposed on the non-connection of road drainage to mains sewers as much for the operational difficulties it creates now and in the future for municipal wastewater treatment plants as for the potential transfer of untreated sewage into watercourses during heavy rain.

However, if stormwater is not combined with sewage and sent to the wastewater treatment plant, it must be discharged to the local watercourse. Prior to any discharge, it is important to allow for the removal of sediments or oils from the stormwater. Sediment removal can be achieved by "hard engineered" components such as road gullies situated under filter drains and concrete tanks that act as oil interceptors or by "soft-engineered" systems. To encourage procurers and tenderers to give more emphasis to "soft engineering" components that address the same problem, award points are offered for soft engineered solutions.

Technical specifications for stormwater retention capacity are included as an example text for those contracting authorities who may be based in a flood risk area but are not fully aware of what can be asked for in a road construction ITT. Experienced authorities will already have very specific requirements to tackle this risk. Where the need for stormwater retention capacity is identified, a variety of technical solutions are available, some involving natural and aesthetically pleasing ponds and basins and others that simply involve concrete tanks. Both follow the same basic hydraulic principles but the former bring environmental benefits and so should receive points at the award stage.

Stakeholder feedback implied that where suitable land is available, landscaping of the roadside can be of high value in the creation of potential habitat, whether this is on the roadside alone or actually as a part of the design for soft-engineered stormwater drainage/retention infrastructure. It is important that the plant species selected are appropriate for the environmental conditions of the site (*i.e.*, soil type, temperature and rainfall) and that they are not high maintenance (in terms of irrigation, fertilizer or pruning).

The importance of overpasses for wildlife in high conservation value areas is recognized but because these structures are to a large extent similar to bridges, which are excluded from the scope of road construction GPP, it was decided not to include any requirements regarding such structures. Furthermore, wildlife overpasses are major works and therefore likely to be subject to a separate ITT. Underpasses for large fauna may be considered as similar to tunnels, which are also out of the scope for road construction GPP, and so are not considered. However drainage culverts, which are relevant both to road drainage and the passage of small fauna, including amphibians and aquatic species, should be considered under this set of criteria. Some culvert designs allow the free passage of animals, including amphibians and fish while others present barriers and can even directly cause harm to fauna, amphibious species or aquatic species that become trapped or injured in the culvert.

Looking at the criteria it may appear that some "double counting" has been done. A vegetated retention basin with infiltration, for example, may be awarded points for pollutant removal and points for stormwater

32 https://online4.ineko.se/trafikverket/Product/Category/11948

retention capacity. This is deliberate because the vegetated basin does provide a better ecological alternative that meets both requirements.

The reasoning for awarding different points to different "soft engineered" solutions in the water pollution and stormwater capacity award criteria is based on the degree of aesthetic benefit and potential for habitat creation or enhancement associated with each solution. Minimum requirements for the % of road length or quantity of drainage routed to the soft-engineered drainage components are set in order to avoid the situation where design solutions that only incorporate very small soft-engineered drainage components are given the same points as designs providing much larger and more comprehensive soft engineered drainage components.

2.4.2 Final criteria proposal

Criteria for introducing water pollution control components in drainage systems

Core criteria	**Comprehensive criteria**
TECHNICAL SPECIFICATIONS	
B3. Performance requirements for water pollution control components in drainage systems *(Unless sewer connections are specifically required by local regulations or specific circumstances)* Road drainage systems shall not be connected to mains sewers. The drainage system shall contain drainage components that aid the removal of any sediment and solid particles from stormwater. **Verification:** The design team *or* the DB tenderer *or* the DBO tenderer shall make it clear where drainage water shall be routed to and where and which sediment removal devices shall be incorporated into the drainage system.	**B3. Performance requirements for water pollution control components in drainage systems** *(Unless sewer connections are specifically required by local regulations or specific circumstances)* Road drainage systems shall not be connected to mains sewers. The drainage system shall contain drainage components that aid the removal of any sediment and solid particles from stormwater. Such "hard engineered" drainage components shall be combined with "soft engineered" components (often referred to as SuDS). **Verification:** The design team *or* the DB tenderer *or* the DBO tenderer shall make it clear where drainage water shall be routed to and where and which sediment removal components/devices shall be incorporated into the drainage system and which of those components/devices follow SuDS principles.
AWARD CRITERIA	
B17. Requirements for water pollution control "soft engineered" components in drainage systems Points will be awarded to drainage system designs that incorporate "soft engineered" components (often referred to as SuDS) as follows: - Filter trenches with low (<25mm) or no kerbs at roadside covering at least 40% of the roadside (0.25X points); - Grassed swales covering at least 40% of the roadside (0.5X points); - Vegetated retention basins with unlined bases for infiltration through which all road drainage is directed prior to reaching the local surface watercourse (0.5X points); - Vegetated retention ponds with linings to create artificial wetlands and/or a permanent water body in all or part of the basin which all road drainage is directed through prior to reaching the local surface watercourse (0.75X points). More than one SuDS feature may be incorporated into the drainage design. These systems shall be designed in accordance with best	**B17. Requirements for water pollution control "soft engineered" components in drainage systems** Points will be awarded to drainage system designs that incorporate "soft engineered" components (often referred to as SuDS) as follows: - Filter trenches with low (<25mm) or no kerbs at roadside covering at least 40% of the roadside (0.25X point); - Grassed swales covering at least 40% of the roadside (0.50X points); - Vegetated retention basins with unlined bases for infiltration through which all road drainage is directed prior to reaching the local surface watercourse (0.50X points); - Vegetated retention ponds with linings to create artificial wetlands and/or a permanent water body in all or part of the basin which all road drainage is directed through prior to reaching the local surface watercourse (0.75X points). More than one SuDS feature may be incorporated into the drainage design. These systems shall be designed in accordance with best

practice guidelines, for example as detailed in "The SUDS Manual C697" published by CIRIA in 2007 or other similar but more recent literature. **Verification:** The design team *or* the DB tenderer *or* the DBO tenderer shall provide details of these drainage solutions and clearly indicate them in the design. Where relevant, reference shall be made to best practice design details and how these are incorporated in the design.	practice guidelines, for example as detailed in "The SUDS Manual C697" published by CIRIA in 2007 or other similar but more recent literature. **Verification:** The design team *or* the DB tenderer *or* the DBO tenderer shall provide details of these drainage solutions and clearly indicate them in the design. Where relevant, reference shall be made to best practice design details and how these are incorporated in the design.
CONTRACT PERFORMANCE CLAUSES	
C6. Inspection of water pollution control components in drainage systems The contractor shall perform site inspection to establish the drainage system dimensions, pathways and connections between drainage components and that these are in accordance with the design plans. Information shall be sent to the contracting authority based upon an agreed timetable. In case of unsatisfactory or non-compliant results, refer to general contract performance clause text in C1.	**C6. Inspection of water pollution control components in drainage systems** The contractor shall perform site inspection to establish the drainage system dimensions, pathways and connections between drainage components and that these are in accordance with the design plans. Information shall be sent to the contracting authority based upon an agreed timetable. In case of unsatisfactory or non-compliant results, refer to general contract performance clause text in C1.
C7. Construction of water pollution control "soft engineered" components in drainage systems The contractor shall perform site inspections both during and after the installation of the vegetated drainage components and ensure that appropriate measures are taken in accordance with best practice guidelines for the establishment of vegetated covers in SUDS drainage components. Information shall be sent to the contracting authority based upon an agreed timetable. In case of unsatisfactory or non-compliant results, refer to general contract performance clause text in C1.	**C7. Construction of water pollution control "soft engineered" components in drainage systems** The contractor shall perform site inspections both during and after the installation of the vegetated drainage components and ensure that appropriate measures are taken in accordance with best practice guidelines for the establishment of vegetated covers in SUDS drainage components. Information shall be sent to the contracting authority based upon an agreed timetable. In case of unsatisfactory or non-compliant results, refer to general contract performance clause text in C1.

Criteria for introducing stormwater retention capacity in drainage systems

Core criteria	Comprehensive criteria
TECHNICAL SPECIFICATIONS	
B4. Performance requirements for stormwater retention capacity in drainage systems *(When required by legislation, or when of particular importance for the specific site)* The drainage system shall be designed to be capable of: - retaining the rainfall from a design storm[33] with a return period (frequency) of 1 in X years and duration of Y minutes across a defined drained area; - restricting maximum runoff rates from the drainage system to no more than that of an equivalent greenfield site or another specific value clearly defined by the contracting authority in the ITT. **Verification:** The design team *or* the DB tenderer *or* the DBO tenderer shall be provided with the appropriate rainfall data for the design storm by the contracting authority.	**B4. Performance requirements for stormwater retention capacity in drainage systems** *(When required by legislation, or when of particular importance for the specific site)* The drainage system shall be designed to be capable of: - retaining the rainfall from a design storm[33] with a return period (frequency) of 1 in X years and duration of Y minutes across a defined drained area; - restricting maximum runoff rates from the drainage system to no more than that of an equivalent greenfield site or another specific value clearly defined by the contracting authority in the ITT. **Verification:** The design team *or* the DB tenderer *or* the DBO tenderer shall be provided with the appropriate rainfall data for the design storm by the contracting authority.

[33] See Figures A.7 and A.8 in Annex 5.

Using this data, they shall run a hydraulic simulation using appropriate modelling software specified by the contracting authority. The simulation shall show that: - At no point during the design storm event is the capacity of the drainage system exceeded and; - At no point during the design storm event does the runoff rate exceed the value specified by the contracting authority.	Using this data, they shall run a hydraulic simulation using appropriate modelling software specified by the contracting authority. The simulation shall show that: - At no point during the design storm event is the capacity of the drainage system exceeded and; - At no point during the design storm event does the runoff rate exceed the value specified by the contracting authority.
AWARD CRITERIA	
B18. Requirements for stormwater retention capacity in drainage systems that incorporate "soft engineered" components Points will be awarded for drainage systems that incorporate "soft engineered" components (often referred to as SuDS) that incorporate stormwater retention devices that improve site aesthetics and contribute to potential habitat creation as follows: - Grassed swales with check dams and an orifice plate at the base to act as retention devices during intense rainfall events but normally be dry (0.50X points); - Vegetated retention basins with unlined bases for infiltration and overflows for severe conditions through which all road drainage is directed prior to reaching the local surface watercourse (0.50X points); - Vegetated retention ponds with linings to create artificial wetlands and/or a permanent water body in all or part of the basin which all road drainage is directed through prior to reaching the local surface watercourse (0.75X points). Any one or all features may be incorporated into the drainage design and may be combined with other "hard engineered" drainage components as per site requirements. These systems shall be designed in accordance with best practice guidelines, for example as detailed in "The SUDS Manual C697" published by CIRIA in 2007 or other similar but more recent literature. **Verification:** The design team *or* the DB tenderer *or* the DBO tenderer shall provide details of these drainage solutions and clearly indicate them in the design. Where relevant, reference shall be made to best practice design details and how these are incorporated in the design.	**B18. Requirements for stormwater retention capacity in drainage systems that incorporate "soft engineered" components** Points will be awarded for drainage systems that incorporate "soft engineered" components (often referred to as SuDS) that incorporate stormwater retention devices that improve site aesthetics and contribute to potential habitat creation as follows: - Grassed swales with check dams and an orifice plate at the base to act as retention devices during intense rainfall events but normally be dry (0.50X points); - Vegetated retention basins with unlined bases for infiltration and overflows for severe conditions through which all road drainage is directed prior to reaching the local surface watercourse (0.50X points); - Vegetated retention ponds with linings to create artificial wetlands and/or a permanent water body in all or part of the basin which all road drainage is directed through prior to reaching the local surface watercourse (0.75X points). Any one or all features may be incorporated into the drainage design and may be combined with other "hard engineered" drainage components as per site requirements. These systems shall be designed in accordance with best practice guidelines, for example as detailed in "The SUDS Manual C697" published by CIRIA in 2007 or other similar but more recent literature. **Verification:** The design team *or* the DB tenderer *or* the DBO tenderer shall provide details of these drainage solutions and clearly indicate them in the design. Where relevant, reference shall be made to best practice design details and how these are incorporated in the design.
CONTRACT PERFORMANCE CLAUSES	
C8. Inspection of stormwater retention capacity in drainage systems The main construction contractor *or* the DB contractor *or* the DBO contractor shall inspect the drainage system during the construction stage to ensure that it follows the agreed design and ensure that it meets the dimensions, slopes and other technical details specified in the design. In case of unsatisfactory or non-compliant results, refer to general contract performance clause text in C1.	**C8. Inspection of stormwater retention capacity in drainage systems** The main construction contractor *or* the DB contractor *or* the DBO contractor shall inspect the drainage system during the construction stage to ensure that it follows the agreed design and ensure that it meets the dimensions, slopes and other technical details specified in the design. In case of unsatisfactory or non-compliant results, refer to general contract performance clause text in C1.
C9. Inspection of stormwater retention capacity in drainage systems that incorporate "soft engineered" components	**C9. Inspection of stormwater retention capacity in drainage systems that incorporate "soft engineered" components**

The main construction contractor *or the* DB contractor *or* the DBO contractor shall carry out site inspections both during and after the installation of the vegetated drainage components and ensure that appropriate measures are taken in accordance with best practice guidelines for the establishment of vegetated covers in SuDS drainage components. In case of unsatisfactory or non-compliant results, refer to general contract performance clause text in C1.	The main construction contractor *or* the DB contractor *or* the DBO contractor shall carry out site inspections both during and after the installation of the vegetated drainage components and ensure that appropriate measures are taken in accordance with best practice guidelines for the establishment of vegetated covers in SuDS drainage components. In case of unsatisfactory or non-compliant results, refer to general contract performance clause text in C1.

Criteria for habitat creation and facilitating the passage of small fauna across the road to reduce the likelihood of wildlife fatalities.

Core criteria	Comprehensive criteria
TECHNICAL SPECIFICATION	
B5. Environmental Integration and Restoration Plan *(This criterion shall apply when suitable land for planting is available, which may include planting in any soft-engineered drainage infrastructure such as retention basins, ponds or artificial wetlands)* An Environmental Integration and Restoration Plan shall be provided as part of the road design that includes the following details: - A site map indicating the type, location and quantities/densities of all plant species (only non-invasive and native plant species shall be included); - A description of the procedure used to select plant species and a brief rationale as to why each species is suitable for the particular environmental conditions on the site; - Planting bed requirements: soil/compost/growing media used and their depths, initial fertiliser application, use of mulch, sowing of grass seeds; - Planned measures to avoid soil erosion both prior to and after the establishment of vegetation cover; - Expected maintenance requirements of the vegetated areas. Included any irrigation, grass cutting, pruning or replacement of plants. The plan should be compiled in accordance with best practice guidelines such as those outlined in the COST 341 report or other similar literature. **Verification:** The design team *or* the DB tenderer *or* the DBO tenderer shall provide a copy of the Environmental Integration and Restoration Plan to the contracting authority.	**B5. Environmental Integration and Restoration Plan** *(This criterion shall apply when suitable land for planting available, which may include planting in any soft-engineered drainage infrastructure such as retention basins, ponds or artificial wetlands)* An Environmental Integration and Restoration Plan shall be provided as part of the road design that includes the following details: - A site map indicating the type, location and quantities/densities of all plant species (only non-invasive and native plant species shall be included); - A description of the procedure used to select plant species and a brief rationale as to why each species is suitable for the particular environmental conditions on the site; - Planting bed requirements: soil/compost/growing media used and their depths, initial fertiliser application, use of mulch, sowing of grass seeds; - Planned measures to avoid soil erosion both prior to and after the establishment of vegetation cover; - Expected maintenance requirements of the vegetated areas. Included any irrigation, grass cutting, pruning or replacement of plants. The plan should be compiled in accordance with best practice guidelines such as those outlined in the COST 341 report or other similar literature. **Verification:** The design team *or* the DB tenderer *or* the DBO tenderer shall provide a copy of the Environmental Integration and Restoration Plan to the contracting authority.
AWARD CRITERIA	
B19. Performance requirements for wildlife passages across the road Points will be awarded for drainage infrastructure (culverts or underpasses) that aids the safe passage of small fauna and amphibious or aquatic species across the road. Points shall be awarded as follows:	**B19. Performance requirements for wildlife passages across the road** Points will be awarded for drainage infrastructure (culverts or underpasses) that allows the safe passage of small fauna, and amphibious or aquatic species across the road. Points shall be awarded points as follows:

- Filter trenches with low (<25 mm) or no kerbs at roadside covering at least 40% of the roadside (0.5X point); - At least 50% of all culverts for the passage of surface water across the road base shall provide flat and dry walkways for small fauna (0.5X point); - All culverts that channel permanent surface water courses do not prevent the upstream migration of fish or amphibious species (0.5X point). Culverts that permit the passage of small fauna or aquatic species shall be designed according to best practice guidelines, for example as published in the COST 341 Handbook or any similar documentation suggested by the contracting authority. **Verification:** The design team *or* the DB tenderer *or* the DBO tenderer shall provide the details of any kerbs, filter trenches or culverts and compare it to best practice guidelines identified by the contracting authority.	- Filter trenches with no kerbs at roadside covering at least 60% of the roadside (0.5X point); - All culverts for the passage of surface water across the road base shall provide flat and dry walkways for small fauna (0.5X point); - All culverts that channel permanent surface water courses do not prevent the upstream migration of fish or amphibious species (0.5X point). Culverts that permit the passage of small fauna, or aquatic species shall be designed according to best practice guidelines, for example as published in the COST 341 Handbook or any similar documentation suggested by the contracting authority. **Verification:** The design team *or* the DB tenderer *or* the DBO tenderer shall provide the details of any kerbs, filter trenches or culverts and compare it to best practice guidelines identified by the contracting authority.
CONTRACT PERFORMANCE CLAUSES	
C10. Commissioning of the Environmental Integration and Restoration Plan During the works, the main construction contractor *or* the DB contractor *or* the DBO contractor shall submit to site inspection of the works site to ensure that the plan has been implemented. Upon completion of the works the main construction contractor *or* the DB contractor *or* the DBO contractor shall submit to a final site inspection of the works site to ensure that the plan, and any agreed deviations from the plan, has been implemented. In case of unsatisfactory or non-compliant results, refer to the general contract performance clause text in C1.	**C10. Commissioning of the Environmental Integration and Restoration Plan** During the works, the main construction contractor *or* the DB contractor *or* the DBO contractor shall submit to site inspection of the works site to ensure that the plan has been implemented. Upon completion of the works the main construction contractor *or* the DB contractor *or* the DBO contractor shall submit to a final site inspection of the works site to ensure that the plan, and any agreed deviations from the plan, has been implemented. In case of unsatisfactory or non-compliant results, refer to the general contract performance clause text in C1.
C11. Inspection of wildlife passages across the road and other measures The main construction contractor *or* the DB contractor *or* the DBO contractor shall undertake inspection of any filter trenches or culverts included in his offer both during and immediately after construction and ensure that they meet the minimum requirements of the technical details specified in the design and that they meet the conditions required for the award of points. In case of unsatisfactory or non-compliant results, refer to general contract performance clause text in C1.	**C11. Inspection of wildlife passages across the road and other measures** The main construction contractor *or* the DB contractor *or* the DBO contractor shall undertake inspection of any filter trenches or culverts included in his offer both during and immediately after construction and ensure that they meet the minimum requirements of the technical details specified in the design and that they meet the conditions required for the award of points. In case of unsatisfactory or non-compliant results, refer to general contract performance clause text in C1.
E7. Commissioning of the Environmental Integration and Restoration Plan During the works, the main construction contractor or the DB contractor or the DBO contractor shall ensure that any appropriate actions are carried out so that the established vegetation cover and habitat quality can be maintained. Such may include but are not limited to: the application of mulch/compost, pruning, replacement of dead plants *etc*... In case of unsatisfactory or non-compliant results, refer to the general contract performance clause text in E4.	**E7. Commissioning of the Environmental Integration and Restoration Plan** During the works, the main construction contractor or the DB contractor or the DBO contractor shall ensure that any appropriate actions are carried out so that the established vegetation cover and habitat quality can be maintained. Such may include but are not limited to: the application of mulch/compost, pruning, replacement of dead plants *etc*... In case of unsatisfactory or non-compliant results, refer to the general contract performance clause text in E4

Summary rationale for the final criteria proposal:

- Technical specifications preventing road drainage being connected to mains sewers will preserve vital sewer capacity, simplify the operation of sewage works and prevent the transfer of untreated sewage to local watercourses during intense rainfall events.
- For the removal of other pollutants, award points are given to green "soft-engineered" solutions only and in proportion to their potential for aesthetic benefits and habitat enhancement. The same approach applies to designs for stormwater retention capacity.
- Factors such as wildlife overpasses and tunnels are considered as out of the scope because these are likely to be decided at the planning stage and both bridges and tunnels are generally excluded from the scope for EU GPP criteria. However, habitat conservation or enhancement via the well-planned landscaping of the roadside and/or stormwater drainage infrastructure is included within the scope. Where drainage culverts are necessary, these can be designed smarter to simultaneously act as safe passages for small animals, amphibians and/or aquatic species. Consequently, points shall be given to such culvert solutions at award stage.

2.4.3 At what stage of the procurement process are the criteria relevant?

The criteria classification, their reference numbers in the criteria document and the respective procurement phase can be cross-referenced as follows:

Title of the criterion	Procurement phase	Criterion classification	Criteria typology	Reference number in the criteria document
Performance requirements for water pollution control components in drainage systems	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B3
Requirements for water pollution control "soft engineered" components in drainage systems	B. Detailed design and performance requirements	Core and Comprehensive	Award criterion	B17
Inspection of water pollution control components in drainage systems	C. Construction	Core and Comprehensive	Contract performance clause	C6
Construction of water pollution control "soft engineered" components in drainage systems	C. Construction	Core and Comprehensive	Contract performance clause	C7
Performance requirements for stormwater retention capacity in drainage systems	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B4
Requirements for stormwater retention capacity in drainage systems that incorporate "soft engineered" components	B. Detailed design and performance requirements	Core and Comprehensive	Award criterion	B18
Inspection of stormwater retention capacity in drainage systems	C. Construction	Core and Comprehensive	Contract performance clause	C8
Inspection of stormwater retention capacity in drainage systems that incorporate "soft engineered" components	C. Construction	Core and Comprehensive	Contract performance clause	C9
Environmental Integration and Restoration Plan	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B5
Performance requirements for wildlife passages across the road	B. Detailed design and performance requirements	Core and Comprehensive	Award criterion	B19
Commissioning of the Environmental Integration and Restoration Plan	C. Construction	Core and Comprehensive	Contract performance clause	C10
Inspection of wildlife passages across the road and other measures	C. Construction	Core and Comprehensive	Contract performance clause	C11
Commissioning of the Environmental Integration and Restoration Plan	E. Maintenance and operation	Core and Comprehensive	Contract performance clause	E7

2.5 Noise criteria

2.5.1 Background technical aspects, discussion and rationale for noise

Technical aspects – Low-noise road surfaces or noise barriers?

Although both low-noise road surfaces and noise barriers contribute positively to the reduction of noise levels in targeted areas, whether one type of approach or the other, or a combination of both is the optimum solution, will depend very much upon the local conditions and nature of the surrounding area.

In terms of life-cycle costs, noise barriers are generally much cheaper than low-noise pavements if the noise reduction benefit in the target area alone is considered. However, when comparing capital and maintenance costs with those of noise barriers, the added function of the provision of an actual pavement surface for vehicles in low-noise pavement solutions should also be taken into account and the expected construction and maintenance costs for a standard asphalt or concrete surface should be subtracted. Such an approach may involve a number of assumptions and generalisations that complicate comparisons. Furthermore, planning permission can be an important issue with noise barriers that would not really apply to low-noise pavements. Finally, a further consideration is that low-noise pavements actually reduce noise emissions in the first place whereas noise barriers often simply prevent a certain fraction of sound-waves reaching a defined low-height target.

Due to the many factors that influence the choice between noise barriers and low-noise pavements, it is recommended that if noise emission is identified as a priority by the contracting authority, then they should also specify in the ITT whether a low-noise pavement or a noise barrier approach (or both together) is desired. Then it should be up to the tenderers to identify the most cost-effective and environmentally friendly solutions based on the particular site specific conditions and constraints.

The following sub-sections (and further details provided in Annex 6) provide some general technical background as a guide to procurers and tenderers on the factors behind noise emissions from roads and the properties that are most important in noise barriers and low-noise pavements. Attention is also given to approaches for specifying low-noise pavements in different countries and regions, techniques that can be used to monitor noise emissions and what are achievable levels of noise reduction. Where available, references to any cost premiums for low-noise surfaces or negative effects on durability will be referred to since these could significantly affect the life cycle cost of the project.

Technical aspects - Sources of noise emission from roads

Noise from roads equates to noise from traffic. The three main sources of road traffic noise are:

- noise from engines and other mechanical parts;
- road-tyre contact;
- air turbulence.

This can be addressed in different ways by low-noise pavements of noise barriers. Further details of technical aspects are provided in Annex 6

Technical aspects - Approaches to low-noise pavements in different countries and regions

Noise measurement requires specialised equipment and technicians and spot data cannot always be directly compared with data from other roads due to background noise from other sources, changes in temperature, wind and humidity and different vehicles passing along the road, each at individual velocities. Furthermore, at the tendering stage, the real noise performance of the road cannot be truly known before it is constructed (or resurfaced). Consequently it is necessary for some system to be in place which allows the procurer to objectively compare different low-noise road surfaces prior to award of the contract. Some approaches used in different Member States are described below.

(i) Denmark

The system used for tendering low-noise asphalt wearing courses by the Danish Road Directorate during the period 2007-2012 is described by Kragh *et al.* (2012). Road surfaces are assessed by approved test laboratories using a calibrated vehicle and trailer equipped with standard reference test tyres that takes CPX measurements at 50 and/or 80kph. Results were then compared to averaged reference data collected from all over Denmark. The most representative road surface used in Denmark was considered to be 8 years old dense graded asphalt. The noise reduction performance of a pavement was then classified AS A (>7 dB less than reference), B (5-7 dB less than reference) or C (3-5 dB less than reference).

Specific guidance was also provided to tenderers on how low-noise asphalt layers should be applied, how the tender documents should be prepared and how the noise-reducing properties should be assessed and declared.

The Danish Road Directorate has identified residential and recreational areas where the annual average L_{den} exceeds 58 dB as priority areas for low-noise pavements. As of 2012, over 30 examples of low-noise pavement contracts had been implemented. Due to concerns with ice formation and freeze-thaw damage, low-noise pavements in Denmark are almost exclusively open-graded thin asphalt pavements with a small maximum aggregate size rather than porous asphalt layers widely used in certain other countries like the Netherlands. Most of these types of pavements were not able to comply with Class A noise performance but only Class B or C.

Possible concerns regarding poorer skid resistance of asphalt pavements with small maximum aggregate sizes have not been substantiated in real life experience from 2007-2012. Concerns due to reduced durability have been encountered in some specific cases and are thought to be linked to the laying of thin-courses during night-time when it is colder and when the thin course is laid on a rougher surface (due to use of a coarse milling drum instead of a fine milling drum to remove the old surface).

From 2012 onwards, a second generation tendering system has been implemented. The baseline reference level has been set based on data from stone mastic asphalt SMA 11 (EN 13108-5). Test data was collected using standard reference test tyres meeting the requirements of ASTM F2493-14. Actual noise levels measured by CPX (Close ProXimity) are converted into estimated SPB (Statistical Pass-By) values using an equation derived from a best-fit trendline when comparing real SPB and CPX data in Denmark. In all cases, the test data should be normalised using correction factors to 20°C. The limits vary depending on the test vehicle speed as per Table 17 below.

Table 17: Danish limits for low-noise pavements as a function of road speed limit.

Speed (kph)	50	60	70	80	90	100	110
SPB reference* Values (dB)	72.0	74.6	76.9	78.9	80.8	82.5	84.1

*calculated by converting CPX values by the following formula: SPB_{ref} = 0.921 x CPX – 13.68.

Prior to the award of a contract, tenderers must declare the expected noise emission performance of the road surface that they propose to lay, which should meet any specific requirements (*i.e.*, >4.0dB(A) reduction at 90kph compared to standard value). This declaration should be supported by real CPX data that they have obtained from specially constructed test sections and using a calibrated trailer.

Contractors are obliged to build two test sections, each at least 100m long, and to demonstrate the low-noise performance of the road by taking CPX measurements according to the guidelines provided by the Danish Road Directorate. Depending on the results, the road is then classified as either "standard noise reducing" (at least a 4.0dB reduction on limits in Table 17) or "special noise reducing" (at least a 7.0dB reduction on limits in Table 17). The current Danish approach only applies to the performance of the test sections of the recently laid road surface and apparently makes no provision for assessment of how its noise reduction performance evolves with ageing.

One example of an ongoing ITT for a noise reducing road surface in a motorway section requires that the new road surface is at least 4.0 dB(A) lower than the standard values in Table 17. Data can be collected at either: 80 or 110kph and should be measured at least 4 weeks after opening. The following conditions apply when comparing actual test data of the constructed road with the requirements of the tender:

- If the noise emission is better than the requirement (*i.e.*, > 4.0 dB(A) reduction) → bonus applies;
- If the noise emission is close to the requirement (*i.e.*, 3.0-4.0 dB(A) reduction) → nothing happens;
- If the noise emission is significantly short of the requirement (*i.e.*, 2.0-3.0 dB(A) reduction) → financial penalty;
- If the noise emission is substantially short of the requirement (*i.e.*, <2.0 dB(A) reduction) → remedial action is required at no additional cost to the contracting authority.

(ii) Italy

In Italy, low-noise road surfaces have been tested as part of several prominent research projects. In particular, in the Tuscany region, significant research into the noise performance of several asphalt pavements has been carried out within the LEOPOLDO project (Licitra *et al.*, 2015a). In the project, acoustical characterization of the low-noise road surface was carried out using the CPX and SPB methods to assess the tyre/road noise contribution and also both the ADRIENNE method and the impedance tube method to evaluate the acoustical absorption of the pavements being tested. The LEOPOLDO project has provided useful guidelines for local administrators for specifying the most suitable low-noise road surface to be used as mitigation action in local urban and sub-urban road construction projects. Moreover, within the project the Environmental Protection Agency of Tuscany (ARPAT) has developed protocols to evaluate the effectiveness of mitigation actions, selecting the CPX method as the best way to assess the acoustical performance of a road surface.

Currently in Tuscany, if a low-noise road surface is to be laid as a noise mitigation action, the tyre/road noise contribution is monitored at least once per year, using the CPX method. A fine spatial resolution is applied to the data obtained, which is useful for identifying very localised areas where noise performance is not adequate and this helps to justify decisions to remove raised crosswalks, manholes or other urban features, and to improve the spatial homogeneity of the acoustical characteristics of the road pavement (Licitra *et al.*, 2014). Particular terms in tenders are going to be developed, in order to oblige the constructor to guarantee a defined noise reduction performance during an agreed period and to take into account the whole road surface installation and its homogeneity. Noise reduction performance is estimated by comparing the low-noise road surface to the pre-existing one or preferably to reference surfaces. Dense Asphalt Concrete or Stone Mastic Asphalt of the same or similar mix design that are laid in the same local area are suggested as possible reference surfaces.

With the motorway network, porous asphalt surfaces have been widely used in Italy. In case of local urban and sub-urban roads, with the exception of research projects, no porous low-noise road surfaces have been tested. However, several experimental rubberized road surfaces have recently been laid and their acoustical performance and time durability are being verified (Licitra *et al.*, 2015b).

(iii) The Netherlands

After increasing the maximum speed limit on highways, in order to compensate for the increased noise emissions, the Dutch government have introduced mandatory requirements for the use of porous asphalt concrete (PAC) on all primary roads. The aim is to have road surfaces with an average annual lifetime noise reduction of 6 dB compared to standard dense asphalt concrete 0/16 (DAC).

With low speed roads (≤.50 kph), experience in the city of Groningen has shown that thin layer surfaces are a much more economical option than porous asphalt both in capital and life cycle costs as well as lifetime noise reduction performance. The approach to contracts taken for low-speed roads in Groningen is to specify an initial noise reduction (C_{road} value – see below) of 4 dB and that this reduction should still be at Least 2 dB after 5 years otherwise the contractor must take remedial action (van Keulen, W., 2009).

To aid with procurement specifications, a system has been developed in this country for the noise classification of road surfaces, providing values known as C_{wegdek} (or C_{road} in English). The system compares the SPB values of a number of standard DAC 0/16 reference roads to the SPB measurements of the new road surface in question. Measurements from at least 5 test sections of the new road must be taken, taking data from at least 100 passenger cars and 50 trucks and making corrections for any temperature differences.

The data must be presented as a regression line with SPB noise plotted against speed and the equation of the line included. For data to be accepted, it is necessary that the 95% confidence interval of noise data is less than or equaL to 0.3 dB at speeds relevant to the road section. Separate plots must be made for passenger car data and "heavy vehicle" data.

(iv) The United Kingdom (UK)

An important part of road planning and maintenance may be linked to the Land Compensation Act (1973) where owners of land or property whose value is adversely affected by a public works are entitled to claim financial compensation up to 7 years after completion of the works. This extends to annoyance due to noise emissions from high traffic volume roads and new by-passes. Anecdotal evidence suggests that the costs of compensation can in some cases amount to a significant percentage of the overall capital cost of a new road construction project.

The Design Manual for Roads and Bridges (DMRB) Volume 11 Section 3 sets out a framework for the environmental assessment of road projects. With regards to technical properties, optionally also including noise emission, these are characterised by Road Surface Influence (RSI) values. Procurers can specify RSI values that are certified by the British Board of Agremont under the Highways Authorities Product Approval Scheme. However, it must be added that the noise performance as reflected by RSI values in no way is linked to the durability of noise reduction performance. Due to a general lack of experience with low-noise pavements, the UK approach is to presume a 3.5 dB reduction in noise emission for porous asphalt layers and a maximum 3.5 dB reduction in thin overlays. These reductions are considered as relevant to that of typical hot rolled asphalt (HRA). The road surfaces traditionally used in the UK are HRA or dense bitumen macadam (DBM) instead of dense asphalt concrete (DAC) or stone mastic asphalt (SMA). According to general noise emission data compiled by Abbott *et al.*, (2010) HRA and DBM are even noisier surfaces than DAC or SMA. Since the UK approach is to consider any surface as a "low-noise pavement" if it has an RSI value Of -2.5 dB, it is possible that some reference surfaces such as DAC and SMA used in Denmark and the Netherlands could potentially be classified as low-noise pavements in the UK.

(v) Sweden

The use of a cost-benefit analysis tool developed by the Swedish National Road and Transport Research Sector (VTI) was suggested in Sweden around 2009. The tool would evaluate which road surface would be the best choice based on the costs and benefits of a proposed road surface compared to that of a standard SMA 0/16 pavement. Costs and benefits would be divided into 4 parts:

- Anticipated lifetime construction and maintenance costs (based on assumptions from the experience of the VTI during simulated wear tests);
- Benefits of noise emission reduction (costs of noise emissions would be based on reductions in the value of private houses and flats. It is unsure to what extent any adverse health effects would be accounted for). This is then linked to the traffic density/speed and the population size that would be affected by the road noise;
- The socio-economic costs of particulate emissions are linked to a specially commissioned study by the VTI;
- The costs/benefits or an increase/decrease in rolling resistance are directly linked to the financial costs of fuel consumption using relationships previously established by the VTI and those of increased/decreased CO_2 equivalent emissions.

The expected impact of this cost-benefit analysis planning tool according to Sandberg is the use of smaller aggregate SMA in medium-high population density areas despite the reduced durability of the surface because this is outweighed by savings due to lower noise emissions and lower rolling resistance. In especially high traffic volume roads with high population densities, the use of porous asphalt surfaces may be calculated as the most cost-effective option, primarily due to low-noise emissions. Anecdotal evidence revealed that the tool had been used on at least two different ITTs but that the durability of the roads constructed from winning designs was less than hoped and that the tool could be used more effectively in the future.

Discussion

Discussion with stakeholders at the meeting and subsequent feedback reflected that, despite the uniform requirements of the Environmental Noise Directive, some Member States were far more experienced than others with road noise mitigation, in particular with low-noise road surface courses. This has been linked to investigation in R&D on low-noise road surfaces and participation in EU FP7 projects, in particular in the Netherlands, Belgium, Denmark, Italy and Sweden.

There was a general agreement that, in the absence of binding local or national legislation, the choice of whether noise mitigation should be included in a road project is ultimately the responsibility of the body that provides planning approval for the road project, whose decision will be linked to the planning process and the associated environmental impact assessment. Some stakeholders supported the inclusion of noise criteria as a minimum technical specification while others stated it should be included as an award criterion only because low-noise pavements are associated with increased capital and maintenance costs. This depends highly on where the road is, the number of vehicles travelling on it, the number of people exposed to the noise coming from this road *etc*... A combination of technical specifications with modest minimum noise reduction requirements and award points for higher performance road surfaces may be the optimum approach. Nonetheless, it must be considered that there are situations where noise emissions are not a major issue, for example in low traffic volume roads. The contracting authority should however not only consider the higher costs of low-noise surfaces, but also the associated direct and indirect benefits on wider issues such as human health and property values.

When noise mitigation is specified, either due to legal/planning obligations or the free decision of the contracting authority, stakeholders stated that the procurer should make it clear in the ITT whether a noise barrier and/or a low-noise road surface is required so that tenders are more specific and easier to compare.

Several Member States' road authorities underlined that there was already collaboration between the bodies responsible for monitoring requirements of the Environmental Noise Directive and Road Authorities for monitoring the noise performance of roads. Collaboration is generally easier if the two departments are grouped under the same Ministry. Multi-functional vehicles for monitoring road surfaces (*i.e.*, roughness, mean profile depth and noise emissions - CPX) are used by some Road Authorities.

Further consultation with some stakeholders led to the understanding that noise mapping and the testing of low-noise road surfaces are not simple overlapping issues. For example, low-noise road surfaces can be measured by the CPX method whereas noise mapping ultimately relies on noise measured at stationary microphones on the roadside. While it may be adequate to normalise road noise data to a single temperature (*i.e.*, 20°C) for ease of comparability of materials and technologies, this would not necessarily be appropriate for noise mapping purposes.

Rationale

Impacts of noise from roads

Environmental noise pollution has been identified as an extremely important but under-regulated impact that affects both human health and wider economic factors such as property value. The importance of the issue is already reflected in Environmental Noise Directive 2002/49/EC, which requires Member States to map noise levels on roads with traffic flows >3 million vehicles per year and in urban agglomerations of >100,000 inhabitants from 2012 onwards.

The dominant source of environmental noise in most urban areas is road traffic and so any efforts to improve environmental noise levels should focus on this area as a priority. The problem is being exacerbated as traffic volumes increase and as populations increasingly migrate from rural areas into urban or metropolitan areas. While the methodologies to estimate the direct and indirect costs of noise pollution are only now being embedded into European law, it is already possible to specify that noise creates annoyance and contributes to higher incidences of cardiovascular disease, strokes, sleep disturbance and tinnitus. The WHO recommends that an outdoor night-time LAEQ of 40 dB and a daytime LAEQ of 55 dB should not be exceeded.

A study by Delft (Van Essen *et al.*, 2011) has estimated the external costs of noise emissions from passenger vehicles on roads to be on average €2/ 1000pkm (passenger kilometres) and from freight vehicles to be €2.5/ 1000 ton.km – adding up to an estimated total of around €20 billion in 2008 across the EU-27.

Relevance within product scope

While factors such as speed limits, tyre design and vehicle design can significantly influence noise from roads, these are outside the scope of the GPP criteria. Low-noise road surfaces however lie within the scope of GPP for road construction. Support was also expressed by stakeholders to include noise barriers in the scope of the criteria because these represent important infrastructure for noise abatement from many roads.

With noise barriers, due to the very site-specific nature of receptor areas and planning objectives of the local authority, the objective for noise reduction should be as clearly defined as possible in the ITT as well as the geographical and planning limits that may apply to noise barriers. This should also include defining at what heights noise exposure should be measured.

With low-noise pavements, there are various levels of performance possible, both in terms of initial noise reduction and the durability of noise reduction performance. As a general rule, if higher noise reduction is required, this will result in higher capital and maintenance costs. For this reason, award criteria are included for low-noise pavements, so that procurers can allow more expensive and superior performance low-noise pavements to become more competitive in the bidding process if they choose to allocate a high amount of award points to this criterion.

Original approach to noise emission from roads proposed at 2nd AHWG meeting:

The original approach was to create separate criteria for low-noise road pavements and for noise barriers, but making it clear that it was up to the contracting authority to decide which way to approach the mitigation of noise emissions from roads if this was identified as a priority issue. This could involve only specifying a low-noise pavement, only a noise barrier or both. In both cases, there was some scope to examine not only performance of the new construction (**conformity** of performance) but also the **durability** of performance.

Low-noise road surfaces

At the second stakeholder meeting, minimum noise reductions of 3.0-4.5 dB(A) compared to a dense asphalt concrete (0/16) or stone mastic asphalt (0/16) or another relevant reference pavement defined by the contracting authority were proposed as technical specifications for new low-noise road surfaces. Although these reductions are achievable with good basic design and construction, this was criticised as too ambitious by stakeholders. Furthermore, stakeholders were concerned about the approach where performance was defined against a reference road. Instead, stakeholders wanted any technical specifications to relate to real and absolute noise emissions that could be directly measured.

A proxy measurement of absolute values of noise emission performance from road surfaces can be quickly determined by using the CPX (Close ProXimity) method, which involves having specially mounted microphones attached to the wheel of a customised test vehicle. The full method is defined in ISO/DIS 11819-2.

Despite the fact that ISO/DIS 11819-2 is currently under revision, it is the standard to follow and should be referred to in GPP criteria, even though the specific technical details of the measurement process may change slightly during the revision. A number of important points to consider when defining the CPX test conditions, and which should be defined in the ITT, are as follows:

- The choice of Standard Reference Test Tyre (SRTT). The tyres previously defined in ISO/DIS 11819-2 are now obsolete and so are no longer representative of true noise emissions from current vehicles. One industry stakeholder has suggested that a useful SRTT to be representative of relatively large passenger cars or vans would be a steel-belted radial tyre with dimensional code P225/60 R16. Industry has committed to continuing to produce this tyre for at least the next 10 years, using the same rubber formulation and the properties are detailed in ASTM F2493-14.
- Weather conditions. It is suggested that any tests should only be carried out during dry conditions and, if the road surface is porous, then no rain should have fallen during the 48 hours prior to the test. Unless the updated ISO/DIS 11819-2 will say otherwise, air temperature should be in the range of 5-30°C and the road surface temperature in the range of 5-50°C when taking measurements.
- Road surface age. CPX tests should not be carried out on new road surfaces prior to opening. This is because the initial road surface properties will change as it is "worn in" by traffic. It is suggested to wait as much as 12 weeks after the road opening before taking the CPX measurement in order to ensure conformity of production. However, in road sections with a heavy traffic load, testing could justifiably be carried out after only 4-6 weeks.
- Test section. The test section should be at least 200m long, begin and end at least 20m from a different road section, be free of any obstacles that would prevent the test vehicle from maintaining a constant speed and should not contain obstacles that stand >1.5m high within a 2m radius of the microphones (excluding the test vehicle of course).
- CPX equipment calibration. This is an ongoing issue that is being addressed in the ROSANNE project and may be an important issue where different equipment is used and results are not directly comparable.

Ambition level for CPX data for low-noise road surfaces

The biggest challenge when setting criteria for low-noise pavements according to CPX data is to decide the point at which a result can be considered as a low-noise road surface and not a "normal" or a "noisy" road surface.

It must be considered that the noise levels from CPX measurements are strongly influenced by vehicle speed. Therefore, limits should be defined as a function of test vehicle speed (which should match the road speed limit for road sections where freely flowing traffic is expected). This criterion should only focus on roads where the dominant noise from vehicles is due to road-tyre contact. Below 40kph, the noise from vehicle engines and powertrains is the most dominant. Bearing this in mind, contracting authorities should realise that low-noise road surfaces have the biggest potential benefit on real-life noise levels in roads where the vehicle speeds are generally in the range of 50-90kph but can also be of value in higher speed road sections.

The classification system for noise-emission performance of road surfaces presented in a report published by Laboratoire Central des Ponts et Chaussées[34] has been compared with the system used in Denmark (see Figure 23).

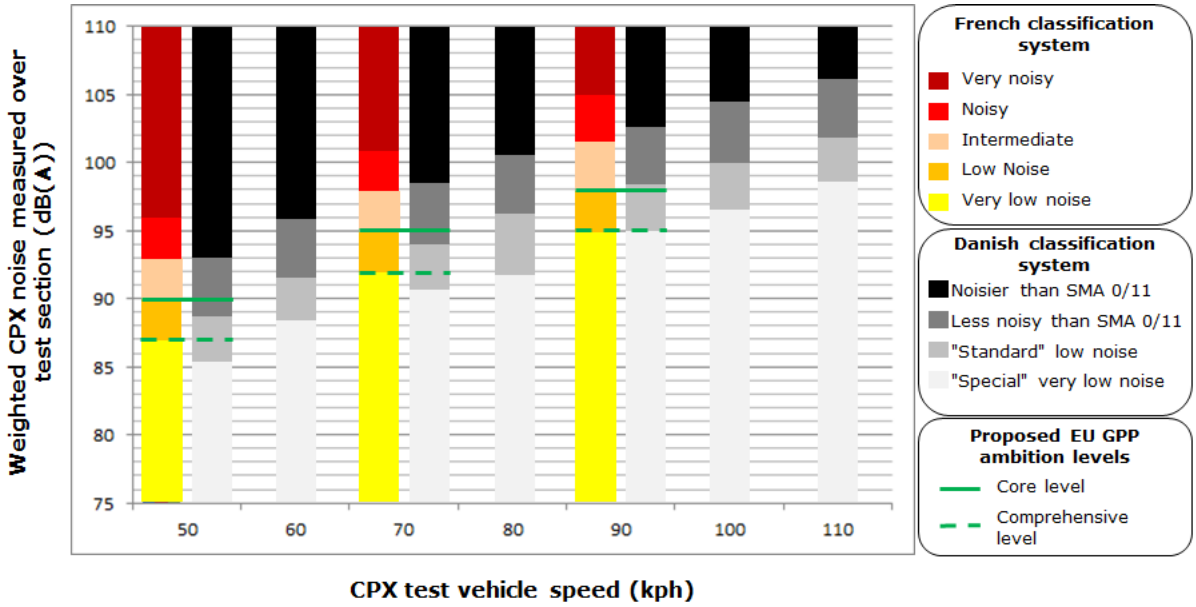


Figure 23. Noise classification based on weighted CPX data (y-axis) and test vehicle speed.

A direct comparison between the French and Danish ambition levels is not possible because the test equipment used in both systems have not been calibrated together. Furthermore, the French system may be based on data using different standard test tyres. Nonetheless, it is interesting to see the general comparability of ambition levels at 50, 70 and 90 kph where both schemes have classification limits in place. The French Class A (very low-noise) road surfaces fall within the range for Danish standard noise reducing surfaces at 50 and 70kph and are very similar to the requirement for Danish special noise reducing surfaces at 90kph.

Where a low-noise road surface forms a fundamental part of an ITT, the contracting authority should make clear what speed limit any CPX test should be carried out at and what minimum level of performance is required. As minimum technical specifications, the following ambition levels for demonstrating conformity of production are to be used:

- **Core level: 90 dB(A) at 50 kph or 95 dB(A) at 70 kph or 98 dB(A) at 90 kph.**
- **Comprehensive level: 87 dB(A) at 50 kph or 92 dB(A) at 70 kph or 95 dB(A) at 90 kph.**

These absolute values equate to the upper allowable limits for low-noise roads (Class B) for the core level requirement or for very low-noise roads (Class A) for the comprehensive level requirement. They are also less noisy than the Danish baseline reference roads and although the core level would not meet the -4.0 dB(A) Danish requirements, the comprehensive level does.

Award criterion

Tenders are evaluated and points awarded prior to the construction of the road. To encourage innovation and novel low-noise road surfaces, an award criterion has been introduced for low-noise road surfaces that exceed the minimum technical specifications. However, in order to discourage overly ambitious claims from tenderers, it is vital that significant and proportional financial penalties apply for non-compliance of design claims when assessing conformity of production once the road has been constructed.

34 Méthode d'essai des lpc no. 63, Version 2.0. Mesure en continu de bruit de contact pneumatique/chaussée, 2008.

To summarise, feedback received during the 2nd round consultation was unanimous in the sense that noise measurement should be based on absolute noise data, which can be gathered quickly and over significant distances that are representative of the entire road section using the CPX methodology. Further details into the precision of the data and the standard reference test tyre were requested to be included directly in the criteria. This was requested, because it is more relevant to tyres used in vehicles today than the existing standard tyres. The tyre industry has committed to continue producing this new standard tyre for the next ten years at least. A new technical standard (ISO 11819-3) is being prepared for this standard reference test tyres but has not yet been finalised. Therefore, specific details have been included in the criterion. This should also ensure a level playing field and ambition level for applying noise criteria in different Member States.

Specific standard reference test tyre details have now been included directly in the criteria as well as minimum requirements for data reliability. The EU GPP ambition level of the CPX noise emission levels for Conformity of Production testing of new roads have been decided by comparison with the French and Danish classification systems.

Durability of performance

A durability of performance criterion has been maintained as a technical specification with associated contract performance clauses. The main reason for this is due to considerable anecdotal evidence that good noise reduction performance in a new road surface is not necessarily an indication of performance over a medium term.

It is proposed that the contractor should ensure that during the first 5 years, CPX data over the same test sections has not increased above the maximum limits in the technical specification by more than 3 dB(A). The time intervals at which CPX measurements are to be taken (*i.e.*, every 6 months, 12 months 18 months *etc.*) should be specified in the ITT.

Although an increase of 3 dB(A) in CPX noise levels does not sound significant when total values are in the range of 75-100 dB(A), due to the logarithmic scale of the decibel scale, a 3 dB(A) increase in noise is equivalent to a 50 % increase in the total acoustic energy and should be distinguishable to human hearing. Figure 17 shows that an increase of 3 dB(A) in CPX noise emissions above the limits set out in the technical specification would potentially move Class A road surfaces into Class B and would move any Class B road surfaces into Class C according to the French classification system.

Noise barriers

Feedback from the 2nd AHWG meeting was generally against the introduction of noise barriers in GPP criteria. It was stated that these are normally built in line with planning regulations and conditions. A report from CEDR (Conference of European Directors of Roads) was cited[35] which showed noise barriers to be the least cost-effective approach to road noise mitigation.

There was a lack of information regarding the potential importance of noise barriers in the implementation of END (Environmental Noise Directive) action plans. This may stem from limited experience to date with such plans and a lack of a uniform approach in different Member States towards noise mapping so far which is being tackled by the ongoing efforts into harmonising the noise mapping methodology across Europe[36].

It is likely that any requirements for noise barriers will be directly linked to planning conditions and/or END action plans in the future. It was pointed out that the choice of materials for a noise barrier of given performance could be relevant to GPP criteria although it is considered most appropriate to include the impact of noise barrier materials within the scope for LCA or CF rather than as a stand-alone GPP criterion.

Due to these considerations, specific stand-alone criterion for noise barriers has been removed from the criteria document although scope for temporary barriers during construction and maintenance works is still included.

35 The European Noise Directive and NRAs: Final summary report CEDR road noise 2009-2013.

36 CNOSSOS-EU (Common Noise Assessment methods in Europe) see: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC72550/cnossos-eu%20jrc%20reference%20report_final_on%20line%20version_10%20august%202012.pdf

2.5.2 Summary of feedback from the 2nd round consultation of stakeholders

Stakeholder feedback received after the 2nd AHWG
During the 2nd AHWG a significant amount of discussion was dedicated to noise criteria and it was considered necessary to undergo a further consultation after the meeting with the most active stakeholders in this area. Feedback received from this further consultation can be summarised as follows: - The application of noise criteria in road construction GPP in Denmark was described more accurately and in greater detail, also referring to a framework for potential penalties and bonuses after Conformity of Production testing of the new road. The importance of the use of calibrated equipment and an appropriate standard reference test tyres was emphasised. - Experience with the LEOPOLDO research project regarding low-noise roads in Italy was described in greater detail and again the importance of using an appropriate standard reference test tyre was emphasised. - The French system for classifying the noise performance of a road surface was presented and suggested as a good basis for the EU GPP criteria. - The need for durability of performance of low-noise road to be a technical specification was emphasised so that certain minimum benefits of noise reduction are ensured at least in the medium-term.

2.5.3 Final criteria proposal

Noise emissions during construction/maintenance

Core criteria	**Comprehensive criteria**
TECHNICAL SPECIFICATIONS	
B6. Monitoring of noise emission during construction and maintenance *(When planning permission or local/national legislation requires, or when specifically requested by the contracting authority)* The design team *or* the DB tenderer *or* the DBO tenderer shall provide details of how temporary noise barriers (or permanent if part of the final design) shall be erected to reduce noise levels in the defined receptor area to less than X dB(A) as averaged L_{dEN} and Y dB(A) as averaged L_{night} values as defined in Annex I of the Environmental Noise Directive (2002/49/EC). **Verification:** The design team *or* the DB tenderer *or* the DBO tenderer shall submit: – a plan of the works site and receptor area as defined by the Environmental Impact Assessment, legislation or contracting authority where relevant; – a timetable of works, highlighting when the most noisy works are to take place; – specification of the noise barrier location and approximate properties coupled with basic acoustic calculations that demonstrate that noise mitigation in the receptor area will be feasible.	**B6. Monitoring of noise emission during construction and maintenance** *(When planning permission or local/national legislation requires, or when specifically requested by the contracting authority)* The design team *or* the DB tenderer *or* the DBO tenderer shall provide details of how temporary noise barriers (or permanent if part of the final design) shall be erected to reduce noise levels in the defined receptor area to less than X dB(A) as averaged L_{dEN} and Y dB(A) as averaged L_{night} values as defined in Annex I of the Environmental Noise Directive (2002/49/EC). **Verification:** The design team *or* the DB tenderer *or* the DBO tenderer shall submit: – a plan of the works site and receptor area as defined in the Environmental Impact Assessment, legislation or contracting authority request where relevant; – a timetable of works, highlighting when the most noisy works are to take place; – specification of the noise barrier location and approximate properties coupled with basic acoustic calculations that demonstrate that noise mitigation in the receptor area will be feasible.

CONTRACT PERFORMANCE CLAUSES	
C12. Monitoring noise emission during construction During construction/maintenance works, the main construction contractor *or* the DB contractor *or* the DBO contractor shall ensure that: – an appropriate noise barrier is in place in accordance with or exceeding the design; – noise levels in the receptor area shall be monitored during the timetable agreed with the contracting authority; – noise data is processed to produce singular L_{den} and L_{night} values for each day during the works timetable that can be compared to the limits agreed upon with the contracting authority. If the L_{den} and or L_{night} values during the agreed monitoring period are found to exceed the limits defined in the accepted tender, the contracting authority can stop the works or introduce penalties as defined in the ITT. Any penalties shall increase in proportion to the product of the number of dB(A) by which the limits were exceeded and the time during which non-compliance occurred.	**C12. Monitoring noise emission during construction** During construction/maintenance works, the main construction contractor *or* the DB contractor *or* the DBO contractor shall ensure that: – an appropriate noise barrier is in place in accordance with or exceeding the design; – noise levels in the receptor area shall be monitored during the timetable agreed with the contracting authority; – noise data is processed to produce singular L_{den} and L_{night} values for each day during the works timetable that can be compared to the limits agreed upon with the contracting authority. If the L_{den} and or L_{night} values during the agreed monitoring period are found to exceed the limits defined in the accepted tender, the contracting authority can stop the works or introduce penalties as defined in the ITT. Any penalties shall increase in proportion to the product of the number of dB(A) by which the limits were exceeded and the time during which non-compliance occurred.
E8. Monitoring noise emission during maintenance *The same as C12*	**E8. Monitoring noise emission during maintenance** *The same as C12*

Criteria for low-noise pavement design

Core criteria	Comprehensive criteria
TECHNICAL SPECIFICATIONS	
B7. Minimum requirement for low-noise pavement *(When local or national legislation requires, or when low-noise levels from this road are considered a priority)* The design team *or* the DB tenderer *or* the DBO tenderer shall declare that the proposed low-noise pavement shall comply with the following close proximity (CPX) noise emission levels according to ISO/DIS 11819-2, as a function of the maximum allowed speed on the road section: - 90 dB(A) at 50 kph, and/or - 95 dB(A) at 70 kph, and/or - 98 dB(A) at 90 kph. Test data used to support the design and any assumptions should account for the use of CPX test vehicles and/or trailers using the steel-belted radial tyre with dimensional code P225/60 R16 as defined in ASTM F2493-14, with a minimum of 5 mm tread. Any test data shall be corrected for a 20°C air temperature. Uncertainty analysis of test data shall be evaluated according to the Guide to the expression of uncertainty in measurement (ISO/IEC Guide 98-3:2008), and the tests shall show that the results, including their uncertainty, are not exceeding by more than 1 dB(A) the values stated above or those claimed with the design (if lower). **Verification:**	**B7. Minimum requirement for low-noise pavement** *(When local or national legislation requires, or when low-noise levels from this road are considered a priority)* The design team *or* the DB tenderer *or* the DBO tenderer shall declare that the proposed low-noise pavement shall comply with the following close proximity (CPX) noise emission levels according to ISO/DIS 11819-2, as a function of the maximum allowed speed on the road section: - 87 dB(A) at 50 kph, and/or - 92 dB(A) at 70 kph, and/or - 95 dB(A) at 90 kph. Test data used to support the design and any assumptions should account for the use of CPX test vehicles and/or trailers using the a steel-belted radial tyre with dimensional code P225/60 R16 as defined in ASTM F2493-14, with a minimum of 5 mm tread. Any test data shall be corrected for a 20°C air temperature. Uncertainty analysis of test data shall be evaluated according to the Guide to the expression of uncertainty in measurement (ISO/IEC Guide 98-3:2008), and the tests shall show that the results, including their uncertainty, are not exceeding by more than 1 dB(A) the values stated above or those claimed with the design (if lower). **Verification:**

The design team *or* the DB tenderer *or* the DBO tenderer shall describe the nature of the proposed low-noise pavement such as aggregate grading, aggregate maximum size, binder used, expected voids volume and expected CPX noise emission from test vehicles at the appropriate speed(s) for the road. The expected noise reduction performance of the new pavement values shall be based on laboratory and/or site measurements of test road sections and may be compared to other well-known low-noise reference surfaces. Data and information may be generated by the tenderer themselves from peer-reviewed published literature or from declarations signed by competent authorities in the field of noise measurement from road surfaces. After opening, a test report, signed by a competent authority, of CPX noise results from testing of agreed road sections at an agreed vehicle speed or speeds shall be provided which demonstrates compliance with the relevant noise emission limits. Spatial variance of the tested road section shall show that no individual parts of the test section exceed these overall limits by more than 2 dB(A).	The design team *or* the DB tenderer *or* the DBO tenderer shall describe the nature of the proposed low-noise pavement such as aggregate grading, aggregate maximum size, binder used, expected voids volume and expected CPX noise emission from test vehicles at the appropriate speed(s) for the road. The expected noise reduction performance of the new pavement values shall be based on laboratory and/or site measurements of test road sections and may be compared to other well-known low-noise reference surfaces. Data and information may be generated by the tenderer themselves from peer-reviewed published literature or from declarations signed by competent authorities in the field of noise measurement from road surfaces. After opening, a test report, signed by a competent authority, of CPX noise results from testing of agreed road sections at an agreed vehicle speed or speeds shall be provided which demonstrates compliance with the relevant noise emission limits. Spatial variance of the tested road section shall show that no individual parts of the test section exceed these overall limits by more than 2 dB(A).
AWARD CRITERIA	
B20. Performance claim for low-noise road pavement design Points will be awarded if the pavement design claims to achieve CPX noise emissions that are >1 dB(A) lower than the minimum technical requirements (see B7). Points will be awarded in proportion to the number of decibels (dB(A) by which the estimated performance improves on the minimum technical requirements. **Verification:** *Same as stated in the verification for criterion* B7.	**B20. Performance claim for low-noise road pavement design** Points will be awarded if the pavement design claims to achieve CPX noise emissions that are >1 dB(A) lower than the minimum technical requirements (see B7). Points will be awarded in proportion to the number of decibels (dB(A) by which the estimated performance improves on the minimum technical requirements. **Verification:** *Same as stated in the verification for criterion* B7.
CONTRACT PERFORMANCE CLAUSES	
C13. Conformity of production testing of low-noise pavement Upon completion of the works, and 4-12 weeks after opening of the road, the main construction contractor, DB contactor or the DBO contractor shall submit to CPX testing for Conformity of Production with the design claims for noise emissions from the road surface by independent and competent third parties. Testing shall be conducted using a customised vehicle and in accordance with ISO/DIS 11819-2. The reference tyres to be used during these tests shall be the P225/60R16 Radial Standard Reference Test Tyre as defined in ASTM F2493-14 and this should be clearly communicated in the ITT. Tests should be carried out under dry conditions and for porous road surfaces, only after at least 2 days since the last rainfall. If the CPX data does not meet the design claims then the DB contractor *or* DBO contractor shall be subject to financial penalties and/or the obligation to carry out remedial works at no additional cost to the contracting authority. If spatial analysis reveals that only one small part of the	**C13. Conformity of production testing of low-noise pavement** Upon completion of the works, and 4-12 weeks after opening of the road, the main construction contractor, DB contactor or the DBO contractor shall submit to CPX testing for Conformity of Production with the design claims for noise emissions from the road surface by independent and competent third parties. Testing shall be conducted using a customised vehicle and in accordance with ISO/DIS 11819-2. The reference tyres to be used during these tests shall be the P225/60R16 Radial Standard Reference Test Tyre as defined in ASTM F2493-14 and this should be clearly communicated in the ITT. Tests should be carried out under dry conditions and for porous road surfaces, only after at least 2 days since the last rainfall. If the CPX data does not meet the design claims then the DB contractor *or* DBO contractor shall be subject to financial penalties and/or the obligation to carry out remedial works at no additional cost to the contracting authority. If spatial analysis reveals that only one small part of the

road section fails to meet the noise limits, any remedial action should apply only to that area. The framework for any applicable penalties or remedial action shall be clearly stated in the ITT.	road section fails to meet the noise limits, any remedial action should apply only to that area. The framework for any applicable penalties or remedial action shall be clearly stated in the ITT.

Criteria for low-noise pavement – durability of performance and testing

Core criteria	**Comprehensive criteria**
TECHNICAL SPECIFICATIONS	
D1. Durability of performance of low-noise pavements *(When local or national legislation requires, or when low-noise levels from this road are considered a priority)* Noise emissions from a low-noise road surface, as measured by the Close Proximity (CPX) method defined in ISO/DIS 11819-2, shall not exceed the following limits, as a function of the maximum speed limit of the road, during the 5 year period after conformity of production testing. - 93 dB(A) at 50 kph, and/or - 98 dB(A) at 70 kph, and/or - 101 dB(A) at 90 kph. Testing shall be carried out at least once during each 30 month period after opening of the road. CPX test vehicles and/or trailers shall use the steel-belted radial tyre with dimensional code P225/60 R16 as defined in ASTM F2493-14, with a minimum of 5 mm tread. Test data shall be corrected for a 20°C air temperature. Uncertainty analysis of test data shall be evaluated according to the Guide to the expression of uncertainty in measurement (ISO/IEC Guide 98-3:2008), and the tests shall show that the results, including their uncertainty, are not exceeding by more than 1 dB(A) the values stated above or more ambitious values claimed with the design. Spatial variance of the tested road section shall show that no individual parts of the test section exceed these overall limits by more than 2 dB(A). **Verification:** Test reports of CPX tests carried out by independent and competent authorities and in accordance with ISO/DIS 11819-2 shall be submitted to the contracting authority and shall comply with the above limits, as appropriate.	**D1 Durability of performance of low-noise pavements** *(When local or national legislation requires, or when low-noise levels from this road are considered a priority)* Noise emissions from a low-noise road surface, as measured by the Close Proximity (CPX) method defined in ISO/DIS 11819-2, shall not exceed the following limits, as a function of the maximum speed limit of the road, during the 5 year period after conformity of production testing. - 90 dB(A) at 50 kph, and/or - 95 dB(A) at 70 kph, and/or - 98 dB(A) at 90 kph. Testing shall be carried out at least once during each 30 month period after opening of the road. CPX test vehicles and/or trailers shall use the steel-belted radial tyre with dimensional code P225/60 R16 as defined in ASTM F2493-14, with a minimum of 5 mm tread. Test data shall be corrected for a 20°C air temperature. Uncertainty analysis of test data shall be evaluated according to the Guide to the expression of uncertainty in measurement (ISO/IEC Guide 98-3:2008), and the tests shall show that the results, including their uncertainty, are not exceeding by more than 1 dB(A) the values stated above or more ambitious values claimed with the design. Spatial variance of the tested road section shall show that no individual parts of the test section exceed these overall limits by more than 2 dB(A). **Verification:** Test reports of CPX tests carried out by independent and competent authorities and in accordance with ISO/DIS 11819-2 shall be submitted to the contracting authority and shall comply with the above limits, as appropriate.
CONTRACT PERFORMANCE CLAUSES	
D2 Durability of performance of low-noise pavements During the 5 year period after conformity of production testing, the main construction contractor *or* the DB contactor *or* the DBO contractor shall submit to CPX testing of noise emissions from the road surface, according to the method defined in the Technical Specification D1, by independent and competent third parties. Tests should be carried out under dry conditions and for porous road surfaces, only after at least 2 days since the last rainfall. If the CPX data does not meet the appropriate limits for the durability of performance criterion, then the DB contractor	**D2 Durability of performance of low-noise pavements** During the 5 year period after conformity of production testing, the main construction contractor *or* the DB contactor *or* the DBO contractor shall submit to CPX testing of noise emissions from the road surface, according to the method defined in the Technical Specification D1, by independent and competent third parties. Tests should be carried out under dry conditions and for porous road surfaces, only after at least 2 days since the last rainfall. If the CPX data does not meet the appropriate limits for the durability of performance criterion, then the DB contractor

or DBO contractor shall be subject to financial penalties and/or the obligation to carry out remedial works at no additional cost to the contracting authority. The framework for any applicable penalties or remedial action shall be clearly stated in the ITT.	*or* DBO contractor shall be subject to financial penalties and/or the obligation to carry out remedial works at no additional cost to the contracting authority. The framework for any applicable penalties or remedial action shall be clearly stated in the ITT.

Summary rationale for the final criteria proposal:

A very brief summary of rationale is provided below:

- Noise emissions during construction can be considered as a minimum technical specification and may be linked directly to the Environmental Impact Assessment as part of the planning process where relevant.
- Low-noise pavements should be set as a minimum technical specification when specifically required either by local/national legislation, planning conditions or when noise levels from this road are considered as a priority concern. Low-noise pavements can achieve significant environmental benefits in most road situations with the exception of low traffic volume roads. The testing requirements are relatively simple and quick to carry out so long as the CPX equipment is available. The tests provide absolute values, avoiding potential problems when attempting to compare performance to reference roads (but increasing the importance that equipment is well calibrated).
- Technical specifications are linked to test vehicle speed and are achievable with materials and technologies already available on the market. Scope for more ambitious approaches is allowed both via the comprehensive level criterion and in a specific award criterion that awards points in proportion to how much a design claims to exceed the minimum technical specification. The importance of the durability of noise reduction performance is reflected in a specific technical specification since good noise performance of a new pavement is not necessarily a reliable indication of its performance over a longer period of time.

2.5.4 At what stage of the procurement process are the criteria relevant

The criteria classification, their reference numbers in the criteria document and the respective procurement phase can be cross-referenced as follows.

Title of the criterion	Procurement phase	Criterion classification	Criteria typology	Reference number in the criteria document
Monitoring of noise emission during construction and maintenance	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B6
Monitoring noise emission during construction Monitoring noise emission during maintenance	C. Construction and E. Maintenance and operation	Core and Comprehensive	Contract performance clauses	C12– E8
Performance claim for low-noise road pavement design	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification + Award criteria	B7 + B20
Conformity of production testing of low-noise pavement	C. Construction	Core and Comprehensive	Contract performance clause	C13
Durability of performance of low-noise pavements	D. Use	Core and comprehensive	Technical specification + Contract performance clause	D1 + D2

2.6 Other environmental criteria

2.6.1 Lighting

For this criterion, please refer to the EU GPP criteria on street lighting and traffic signals.

Core criteria	Comprehensive criteria
TECHNICAL SPECIFICATIONS	
B8. Performance requirement for lighting installations For this criterion, please refer to the EU GPP criteria for street lighting and traffic signals. http://ec.europa.eu/environment/gpp/pdf/criteria/street_lighting.pdf **Verification:** See the respective EU GPP criteria documents.	**B8. Performance requirement for lighting installations** For this criterion, please refer to the EU GPP criteria for street lighting and traffic signals. http://ec.europa.eu/environment/gpp/pdf/criteria/street_lighting.pdf **Verification:** See the respective EU GPP criteria documents.

2.6.2 Road markings

Criteria for "Road markings" are under development and are expected to be published soon on the GPP webpage of the Commission.

Core criteria	Comprehensive criteria
TECHNICAL SPECIFICATIONS	
B9. Performance requirement for road markings For this criterion, please refer to the EU GPP criteria for paints, varnishes and road markings, to be published soon at: http://ec.europa.eu/environment/gpp/eu_gpp_criteria_en.htm **Verification:** See the respective EU GPP criteria documents.	**B9. Performance requirement for road markings** For this criterion, please refer to the EU GPP criteria for paints, varnishes and road markings, to be published soon at: http://ec.europa.eu/environment/gpp/eu_gpp_criteria_en.htm **Verification:** See the respective EU GPP criteria documents.

2.7 Congestion

2.7.1 Background technical discussion and rationale for congestion

Congestion is caused by lane and road closures necessary for road construction and/or maintenance. It can greatly influence vehicle fuel consumption due to queues and associated slowdown (Taylor P. *et al.*, 2012).

Santero *et al.* (2011a) hypothesize that congestion could be a much greater portion of a pavement's environmental impact than construction materials and equipment and conclude that the environmental impacts associated with congestion are dependent upon the project and site characteristics. For low traffic rural and local roads, the impacts of congestion are likely to be negligible. Conversely, on motorways and highways, the extra fuel consumption and related air emissions can easily become a prominent component of the pavement life cycle. From an environmental perspective, a long-life pavement with high durability has less need for lane closure and thus reduces the impacts of congestion.

According to Huang *et al.* (2009), in order to reduce the environmental impacts of road maintenance works, effective traffic management (lane closure, traffic diversion) and phasing of the roadwork into off-peak hours (night shifts) have to be planned. Moreover, planning the use of hard shoulders during peak-hours could be beneficial in order to decrease congestion.

CEDR report 'Comparison of the congestion policies of national road authorities' (CEDR, 2011) analyses some policy interventions and programmes to prevent and mitigate the congestion in roads:

- *Physical expansion of capacity*
    - Major projects to add capacity to traffic corridors, such as adding lanes to roads, building new road links, by-passes, improving large intersections, shortening of planning procedures to speed-up delivery of projects, new design/construct contracts, centralisation of planning and realisation.
    - Minor road construction projects at specific bottlenecks and junctions, which often give a high benefit-to-cost ratio.
- *Better management of capacity*
    - Management of roadworks by optimising planned roadworks and using ITS to optimise traffic operations and reduce the socio-economic costs of the roadworks; a construction site management system to optimise the timing and planning of works; innovative quickchange moveable barriers to reduce the time needed to set out traffic management and to improve the safety of the on-road workforce; a new regulatory framework providing organisational and technical specifications; improvement of the co-ordination of roadworks between different road authorities.
    - Incident and accident management, including procedures and training for contractors. In the UK, there is a dedicated traffic officer service to manage traffic, clear debris from motorways, and order the removal of abandoned, broken down and accident-damaged vehicles from the motorway network. In France, on days when traffic is heavy and likely to cause disruption, traffic progress is monitored in real time by the police and gendarmerie and operations are adjusted accordingly, including the setting of signs to control access or the provision of alternative routing information.
    - Intelligent Transport Systems (ITS) at bottlenecks, *e.g.*, information signs, queue warning, variable message signs (VMS), travel times shown on a website, travel times shown on VMS, CCTV images on the internet, dynamic speed limits to harmonise the distribution of traffic, ramp metering, temporary use of the hard shoulder, dynamic lane management, and strategic diversions of traffic.
    - Heavy Goods Vehicles (HGV): Overtaking bans on some stretches of the network for lorries, and regular checks of lorries to identify dangerous loads that might cause accidents, HGV tolling schemes, and the testing of anti-tilting devices.
    - Winter road operations, including 24/7 maintenance on motorways, intelligent use of thawing agents, and spraying systems at particular hotspots. Bad weather plans are in place in France in 7 'defence zones' to minimise the impact of heavy snowfall and ice on

the network. These plans contain a variety of interventions including priority salting, traffic control, and diversions with decision-making being coordinated between all of the affected defence zones.

 - Management of major events through dissemination of information, the implementation of traffic management on the network, and the provision of guidance on best practice.
 - Creating parking areas for pool driving or parking areas at public transportation terminals to support the transfer between private cars and public transportation, thereby reducing the traffic volume.

- *Information systems*
    - Influencing driver behaviour through pre-trip information services to help drivers avoid congestion and make other journey choices (other modes) and by providing on-trip information.
    - Collection of data to improve knowledge of where congestion is a problem and to contribute to decision-making on solutions; implementation of a nationwide data warehouse.

Berkum and Huerne (2014) presented a multi-objective framework where for a longer period of time, cost and hindrance of specific road maintenance works can be determined, as part of a decision support tool for the optimal planning of maintenance works. For this they developed an alternative traffic assignment method that is able to predict traffic flow in a network in the presence of road works. Figure 24 shows effects on two criteria (cost and hindrance) that were calculated using that framework, for different solutions of a road maintenance project. This tool enables the procurer to make a decision based on the Most Economically Advantageous Tender, as suggested by one of the stakeholders.

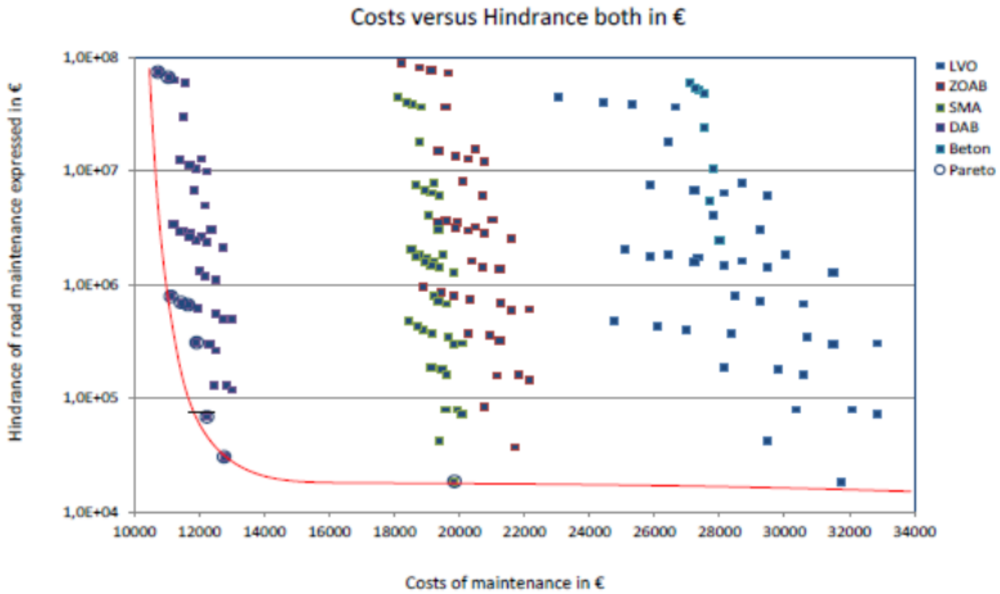


Figure 24: Cost of maintenance versus hindrance costs of road maintenance activities (Berkum and Huerne, 2014).

Previous draft criteria area for congestion and stakeholders consultation

This criteria area is fully linked to the construction and maintenance activities, thus the ITT for such services should include a requirement on a Traffic Congestion Mitigation Plan that includes:

- Timeline including expected construction and/or maintenance activities for the road service life.
- Where necessary, alternative routes for diverted traffic during such activities will be provided. The use of hard shoulders should be specified.

The procurement contract would contain a clause or clauses committing the party responsible for planned maintenance to carry out such works during off-peak hours only and, where seasonal traffic fluctuations are high, during off-season periods.

Another key issue on the management of the traffic congestion is related to the information provided to the user. Thus, the road should be equipped with traffic management devices: traffic lights, information screens and variable road signs. Although the scope of the study does not cover this type of elements, meaning the criteria are not expected to include specific requirements for those elements, it is reasonable to consider the possibility of such equipment to be part of the traffic management requirements to minimize traffic congestions.

Stakeholders have pointed out that the communication is a key tool to enable travellers in advance to make good decisions. Contractors are asked (via Most Economically Advantageous Tender) to reduce the number of lost vehicle hours. Contractors are responsible both for elaborating and realising these measures.

Another comment pointed out that though the use of criteria on the availability of the carriageway (*e.g.*, number of open lanes in various time slots per day), together with penalties in case such criteria are not met, contracting authorities could steer congestion potentials, also for maintenance works.

The use of tidal flow lanes was also suggested to ease traffic congestion in peak hours.

During the 2nd round of consultation, a stakeholder underlined that tenderers are not providing global solutions for congestion and it is the specific responsibility of the NRA/local authority for traffic management to set up the road scheme plans, because they set up the larger traffic and road solutions either for provinces or even nation-wide. In this regard, the Traffic Congestion Mitigation Plan inevitably refers only to the specific road project but it could help the NRA/local authority to better plan the traffic management system of the entire road network.

2.7.2 Final criteria proposal

Core criteria	**Comprehensive criteria**
TECHNICAL SPECIFICATIONS	
B10. Traffic Congestion Mitigation Plan A Traffic Congestion Mitigation Plan to be implemented during construction and maintenance activities, shall be presented with the road design and include: – A timeline with expected construction and/or maintenance activities for the road service life; – Alternative routes for diverted traffic during such activities, if necessary. If the design team *or* the DB tenderer *or* the DBO tenderer includes congestion solutions during the use phase and any maintenance actions based on tidal flow lanes or hard shoulders to be used as lanes, they shall present an LCC analysis, including user cost externalities due to congestion. For those roads where Intelligent traffic systems (ITS) are implemented for traffic management, the road shall be equipped with the devices needed to support the ITS: cameras, traffic lights, information screens and variable road signs. **Verification:** The design team *or* the DB tenderer *or* the DBO tenderer shall provide the detailed traffic congestion mitigation plan, the LCC analysis in accordance with ISO 15686-5 (if required) and the descriptions of the ITS devices (if required).	**B10. Traffic Congestion Mitigation Plan** A Traffic Congestion Mitigation Plan to be implemented during construction and maintenance activities, shall be presented with the road design and include: – Timeline with expected construction and/or maintenance activities for the road service life; – Alternative routes for diverted traffic during such activities, if necessary. If design team *or* the DB tenderer *or* the DBO tenderer includes congestion solutions during the use phase and any maintenance actions based on tidal flow lanes or hard shoulders to be used as lanes, they shall present an LCC analysis, including user cost externalities due to congestion. For those roads where Intelligent traffic systems (ITS) are implemented for traffic management, the road shall be equipped with the devices needed to support the ITS: cameras, traffic lights, information screens and variable road signs. **Verification:** The design team *or* the DB tenderer *or* the DBO tenderer shall provide the detailed traffic congestion mitigation plan, the LCC analysis in accordance with ISO 15686-5 (if required) and the descriptions of the ITS devices (if required).
CONTRACT PERFORMANCE CLAUSES	
C14. Commissioning of the Traffic Congestion Mitigation Plan The main construction contractor *or* the DB contractor *or* the DBO contractor shall provide documentary evidence of the correct implementation of the Traffic Congestion Mitigation Plan.	**C14. Commissioning of the Traffic Congestion Mitigation Plan** The main construction contractor *or* the DB contractor *or* the DBO contractor shall provide documentary evidence of the correct implementation of the Traffic Congestion Mitigation Plan.

The contracting authority will verify the specific requirements for congestion (ITS devices, tidal flow lanes and hard shoulder) after the construction before the road opening and 6 months after the opening (in-service road). The main construction contractor *or* the DB contractor *or* the DBO contractor shall, in case of a significant deviation from the Traffic Congestion Mitigation Plan proposed in the design phase is considered necessary, inform the contracting authority and agree, if justified, upon any deviation. In case of unsatisfactory or non-compliant results, refer to general contract performance clause text in C1.	The contracting authority will verify the specific requirements for congestion (ITS devices, tidal flow lanes and hard shoulder) after the construction before the road opening and 6 months after the opening (in-service road). The main construction contractor *or* the DB contractor *or* the DBO contractor shall, in case of a significant deviation from the Traffic Congestion Mitigation Plan proposed in the design phase is considered necessary, inform the contracting authority and agree, if justified, upon any deviation. In case of unsatisfactory or non-compliant results, refer to general contract performance clause text in C1.
E9. Commissioning of the Traffic Congestion Mitigation Plan *The same as* C14.	**E9. Commissioning of the Traffic Congestion Mitigation Plan** *The same as* C14.

Summary rationale for the final criteria proposal:

- Congestion is caused by lane and road closures necessary for road construction and/or maintenance. It can greatly influence vehicle fuel consumption due to queues and associated slowdown.
- In order to reduce the environmental impacts of road maintenance works, effective traffic management (lane closure, traffic diversion) and phasing of the roadwork into off-peak hours (night shifts) have to be planned. Moreover, planning the use of hard shoulders during peak-hours could be beneficial in order to decrease congestion.
- Also specific design requirements could be requested for the road construction: tidal flow lanes and devices to support the Intelligent Traffic Systems of the Traffic Management Authorities.

2.7.3 At what stage of the procurement process are the criteria relevant?

The required road capacity (number of lanes and appropriate speed limit) will be defined based on current and possibly future predicted traffic flows in the preliminary scoping and feasibility. Furthermore, the congestion might be caused by an ill-designed capacity of the road. It is recommendable to study the traffic flow expected on the road along its lifetime, especially in urban roads as rings and distributors. In those cases, the decision on the road capacity should take into account the land-use plan of the urban area and the future demographic scenarios. For this purpose, it is suggested to take into consideration in the strategic planning the following: t*he road capacity design will be compared with modelling of future traffic flow during its design service life – taking into account land-use planning in the road catchment area and accounting for different future demographic scenarios*.

The design team, DB tenderer or DBO tenderer should provide a preliminary Traffic Congestion Mitigation Plan in the detailed design and performance requirements. Moreover, traffic management devices as traffic lights, information screens and variable road signs should be planned in order to manage congestion.

Implementation and verification of the detailed design (ITS devices, tidal flow lanes and hard shoulder) is proposed in the construction phase. Specific contract clauses related to planned maintenance commitments are proposed to be included in the maintenance phase.

The criteria classification, their reference numbers in the criteria document and the respective procurement phase can be cross-referenced as follows.

Title of the criterion	Procurement phase	Criterion classification	Criteria typology	Reference number in the criteria document
Traffic Congestion Mitigation Plan	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B10
Commissioning of the Traffic Congestion Mitigation Plan	C. Construction	Core and Comprehensive	Contract performance clauses	C14
Commissioning of the Traffic Congestion Mitigation Plan	E. Maintenance	Core and Comprehensive	Contract performance clauses	E9

2.8 Maintenance and rehabilitation strategies

2.8.1 Durability

2.8.1.1 Background technical discussion and rationale for durability

Pavement durability is a key factor in determining the performance of a pavement material and the pavement service lifetime, together with the pavement maintenance requirements (Nicholls *et al.*, 2014). In the EARN project (see Table 18), it is highlighted, for example, that the durability of an asphalt pavement involves many relevant parameters and could be classified as follows:

- The effects from traffic and weather as well as environmental and sub-base soil conditions.
- The parameters for unbound base courses, hydraulically bound base courses and bituminous bound base and surface courses.

Some of the parameters that affect durability can be controlled by material and pavement engineering (*e.g.*, mix design, raw material selection, and pavement design) while others are ancillary conditions which cannot be modified during road design and construction (*e.g.*, weather conditions).

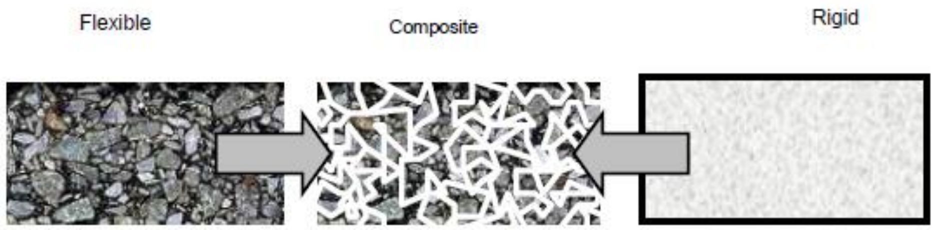
Table 18: Parameters affecting the durability of road materials for flexible pavements (Nicholls *et al.*, 2014).

Categories	Parameters
Environmental effects	Air Temperature, wind speed Sun exposure Frost-Thaw-Cycles Precipitation, humidity High-depth frosting
Traffic loading	Tyre/Axle load; weight and number Traffic Speed (distribution) Axle configuration
Sub-base characteristics	Bearing capacity Sub-base moisture / drainage properties
Pavement type and structure	Type of pavement Number of structural layers Layer thickness Interlayer bonding
Unbound base courses	Composition (type of aggregates, grading) Degree of compaction Moisture Bearing capacity
Hydraulically bound base courses	Construction type Void content Grading of aggregates Stiffness / Strength Binder type Binder content Construction conditions: Shrinkage / cracking
Bitumen stabilised base courses (Cold recycling mixtures)	Type of mixture (foam or emulsion; site or plant mixed) Aggregate grading Curing conditions Binder content (bitumen) Stiffness / Strength Binder content (cement) Void content
Asphalt courses (hot, half-warm and warm mix asphalts)	Type of mixture Type and content of additives Aggregate grading RA type, quality and content Binder type Construction conditions Binder content Performance properties Air voids content and volumetric properties

During the 2nd round of consultation, stakeholders suggested to better define the durability, considering that it varies depending on various factors, such as traffic flow, heavy traffic, available materials, climate, *etc*... The relative importance of parameters such as water sensitivity, rutting, studded tyre wear, reflective cracking, thermal cracking, ageing or fatigue varies considerably between different EU countries.

The deterioration rate of construction materials depends not only on their mechanical and chemical properties but also on appropriate design and construction of the road. These factors will have an important influence on the service life of the road and its needs for maintenance.

According to an OECD Report (OECD 2005), paving materials can be grouped into one of four main categories: asphaltic, cementitious, composite or synthetic. The end products can have attributes akin to existing flexible and rigid pavements, or somewhere in between. As shown in Figure 25, the overall trend is to increase the strength of flexible systems and increase the flexibility of rigid systems.



Source: Author.

Figure 25: Scheme for flexible, composite and rigid pavements (OECD, 2005).

The report also contains a qualitative ranking of various materials with regard to construction and maintenance issues as well as end-users and other societal issues. Materials included in this comparison are highly modified reacted asphalt, reactive modified asphalt, synthetic binder, asphalt-cement composite, and high-performance cementitious materials. A lower number reflects beneficial qualities for the particular criterion. 'Anticipated lifetime' means the service lifetime of the road pavement until its rehabilitation.

Table 19: Comparison of various materials (OECD, 2005).

	Flexible systems	< -- >	Rigid systems		
	Reacted modified asphalts	Reactive modified asphalts	Synthetic binders	Composites	Reactive powder concrete
Design	1	2	2	2	1
Testing	1	2	2	2	1
Production	On site	On/off site	On/off site	On site	Off site
Construction	112	21-32	21-32	22-32	22-32
Complexity	1	2	2	2	2
Speed	1		1-3		2-3
Ease of paving	2	2	2	2	2
Health and safety	122	211	211	111	1-211
Worker health	1	2	2	1	1-2
Fire hazard	2	1	1	1	1
Spill damage	2	1	1	1	1
Maintenance					
Ease	1	2	2	2	2
Anticipated cost	3	2	2	3	1
User criteria					
Smoothness	1	1-3	1-3	1	1-3
Noise	1	1-2	1-2	2	3
Skid resistance	2	1	1	2	3
Splash	1	1	1	2	3
Ability to recycle	Completely	Yes	Yes	Yes	Yes
Anticipated lifetime					
Years	15-25	20-30+	20-30+	15-25	40+
Cost	2	2-3	3	2	4

Note: Lower number indicates beneficial qualities.

As it is shown in the Table 19, a compromise between the different considerations should be reached to attain the optimized solution, particularly in terms of lifetime and costs of construction and maintenance. The most durable materials might entail larger costs of construction, but those expenses could be offset by means of lower maintenance requirements.

The information available in the LCC analysis (see section 3.3 describes different maintenance needs (routine, preventive and rehabilitation) for real case studies of flexible, rigid and semi-rigid pavements (see Table 20, Table 21, Table 22, Table 23 and Table 24). Some stakeholders pointed out that this data appears to be inconsistent (for example, shorter periods for the first maintenance activities are suggested for some lower traffic roads in comparison to the ones for highways). However, it has to be considered that, because this data refers to real case studies, the specified maintenance frequencies might not be applicable to other projects where different weather conditions, traffic loads, construction techniques, materials, *etc.* apply. For example, with reference to Table 4, which states that 12-15 years can be allowed before joints need to be resealed, one stakeholder underlined that experience in Germany showed that 8-10 years would be more realistic.

Table 20: Expected frequencies of routine maintenance on flexible pavements.

Flexible	Scenario	Truck Traffic AADTT	Maintenance	per 1 km road	First maintenance activity after construction (year)	Frequency after the first activity (years)
ARA, 2011	Motorway highway	High	Crack sealing Pothole repair	100-500 m 5-10%	8 8	5-8 5-8
		Medium	Crack sealing Pothole repair	100-500 m 5-10%	5 10	5-10 10
		Low	Crack sealing Pothole repair	100-500 m 5-10%	5 10	5 10
	Secondary /regional roads	High	Crack sealing Pothole repair	100-500 m 5-10%	10 10	5-10 8-10
		Medium	Crack sealing Pothole repair	250-500 m 2-10%	10 10	5-10 5-10
		Low	Crack seal Pothole repair	250-500 m 2-5%	10 10	5-10 10
COWI, 2014 (based on data V&S, 2011)	Local roads		Crack sealing Pothole repair	5% of surface per year [c)]		After 3-5
Federbeton 2010	Motorway /highway		Crack sealing Pothole cracking		4 4	7 1(after 4)
Motorway/highway (2 lane per carriageway): High: AADTT 10000 Medium: AADTT 5000-7000 Low: AADTT 2500				Secondary/regional roads (1 lane per carriageway): High: AADTT 1500 Medium: AADTT 500-1000 Low: AADTT 250		
				A lane width of 3.5-3.75 meters		

Table 21: Expected frequencies of routine maintenance on rigid and semi-rigid pavements.

	Pavement	Scenario	Truck Traffic AADTT	Maintenance	per 1 km road	First maintenance activity after construction (year)	Frequency after the first activity (years)
ARA, 2011	Rigid	Motorway /highway	High	Reseal joints	50%	12	12-15
			Medium	Reseal joints	25%	12	12-15
			Low	Reseal joints	25%	12	12-15
	Rigid	Secondary /regional	High	Reseal joints	20-25%	12	12-15
			Medium	Reseal joints	10-20%	12	12-15
			Low	Reseal joints	10-20%	12	12-15
Motorway/highway (2 lane per carriageway): High: AADTT 10000 Medium: AADTT 5000-7000 Low: AADTT 2500					Secondary/regional roads (1 lane per carriageway): High: AADTT 1500 Medium: AADTT 500-1000 Low: AADTT 250		
					A lane width of 3.5-3.75 meters		

Table 22: Expected frequencies of preventive maintenance of flexible pavements.

Flexible	Type	Truck Traffic AADTT	Maintenance	Thickness (mm)	First maintenance activity after construction (year)	Frequency after the first activity (years)
ARA, 2011	Motorway /highway	High	Milling and replace	50-90	32	
		Medium	Milling and replace	40	32 20	13-15
		Low	Milling and replace	40	20	13-15
	Secondary /regional roads	High	Milling and replace	40-90	20	28
		Medium	Milling and replace	40	20	28
		Low	Milling and replace	40	20	28
COWI, 2014 (based on data V&S, 2011	Local	Low	Patching		After 5	
			Fog seal		After 5-7	
			Chip seal		After 7-10	
			Recycling		After 10	
Federbeton 2010	Motorway /highway		Milling and replace		7	7
Motorway/highway (2 lane per carriageway): High: AADTT 10000 Medium: AADTT 5000-7000 Low: AADTT 2500				Secondary/regional roads (1 lane per carriageway): High: AADTT 1500 Medium: AADTT 500-1000 Low: AADTT 250		
				A lane width of 3.5-3.75 meters		

Table 23: Expected frequencies of preventive maintenance of rigid and semi-rigid pavements.

Rigid and semi-rigid	Type	Truck Traffic AADTT	Maintenance	% on 1 km of road	First maintenance activity after construction (year)	Frequency after the first activity (years)
ARA, 2011	Motorway /highway	High	Partial depth repair	5	12	12-15
		Medium	Partial depth repair	2-5	12	12-15
		Low	Partial depth repair	2-5	12	12-15
	Secondary /regional roads	High	Partial depth repair	5	25	12-15
		Medium	Partial depth repair	2-5	25	15-25
		Low	Partial depth repair	2-5	25	15-25
Federbeton 2010	Motorway /highway	(Semi-rigid)	Cracking longitudinal joint Punch out and deterior.		13 10	7 10
Motorway/highway (2 lane per carriageway): High: AADTT 10000 Medium: AADTT 5000-7000 Low: AADTT 2500				Secondary/regional roads (1 lane per carriageway): High: AADTT 1500 Medium: AADTT 500-1000 Low: AADTT 250		
				A lane width of 3.5-3.75 meters		

Table 24: Expected frequencies of rehabilitation of flexible pavements.

Flexible	Type	Truck Traffic AADTT	Maintenance	% per 1 km of road	First Activity after initial construction (year)	Frequency after the first activity (years)
ARA, 2011	Motorway /highway	High	Full depth repair	10	18	27
		Medium	Full depth repair	5-10	18 48	27
		Low	Full depth repair	5	48	
	Secondary /regional roads	High	Full depth repair	10	35	
		Medium	Full depth repair	5	35	
		Low	Full depth repair	5	35	
COWI, 2014 (based on data V&S, 2011	Local	Low	New overlay with: HMA WMA CMA			After 15-20 years
Federbeton 2010	Motorway /highway		Full depth repair		28	28
Motorway/highway (2 lane per carriageway): High: AADTT 10000 Medium: AADTT 5000-7000 Low: AADTT 2500				Secondary/regional roads (1 lane per carriageway): High: AADTT 1500 Medium: AADTT 500-1000 Low: AADTT 250		
				A lane width of 3.5-3.75 meters		

The data collected in the tables above shows that the frequency of maintenance depends not only on the type of material, and its resistance against environmental conditions, but also on the type of road (*i.e.*, motorway or secondary road) and, in the case of flexible pavements, on the proportion of truck traffic borne by the road. Nevertheless, it seems reasonable to set a common minimum durability expressed as time, for all type of roads (motorway or secondary roads, and different rates of heavy traffic), which would determine the design of the road in terms of materials and construction techniques.

Within the research project Consistend[37] (CEDR Call 2013: Energy Efficiency), a tool is being developed to calculate the durability based on simple input parameters for climate, material, process and traffic intensity. Factors affecting the service lifetime have been identified in:

- **Design parameters**: *i.e.*, choice of materials, pavement thickness and volumetric (*e.g.*, void contents, bitumen percentage *etc.*);
- **Construction**, *e.g.*, degree of compaction, temperature and humidity;
- **Service life conditions**:
    - **Climatic conditions:** mainly temperature and precipitation;
    - **Traffic conditions**: mainly traffic intensity, speed and truck percentage.

37 Consistend. A tool to assess the impact of construction process quality on the performance of pavements and its implementation in tenders. Information available at http://www.cedr.fr/home/fileadmin/user_upload/en/Thematic_Domains/Strat_plan_3_2013-2017/TD1_Innovation/I1_Research/TGR_TPM/CEDR_Call_2013_information_June2014.pdf

According to the EARN project (Nicholls *et al.*, 2014 – ERA-Net II research project), the current state of the art on the durability of pavements should be described in terms of the assumptions used to develop the Pavement Management System (PMS). PMS is a usually a computer-aided tool used for analysing maintenance and rehabilitation (M&R) strategies in the framework of the Asset Management (AM). The current assumptions of the nominal service lifetime for some countries such as Germany, the Netherlands and the UK have been provided (Table 25).

Table 25: Example of nominal service lifetime assumptions for PMS provided in the EARN project (Nicholls *et al.*, 2014).

Road layer	Pavement material	Germany (FGSV, 2001)		Netherlands (IVON, 2012)		UK (SWEEP Pavements, 2013)	
		≥ 300 ESAL/day	< 300 ESAL/day	Right hand lane	Full width	surface life	structural life
Surface asphalt layers	Asphalt concrete (AC)	12	18	12	18	8	–
	Very thin layer asphalt concrete (BBTM)	–	–	–	–		
	Hot rolled asphalt (HRA)	–	–	–	–		
	Stone mastic asphalt (SMA)	16	22	11	17		
	Mastic asphalt (MA)	19	26	–	–		
	Porous asphalt (PA)	–	–	10	18		
Asphalt base layers	Asphalt concrete (binder layer)	26	30	–	–	–	20
	Asphalt concrete (base layer)	55	75	*	*		
	Other base layers						
	Hydraulically bound base layer	60	80	*	*		
	Unbound base layer	55	75	*	*		
Rigid pavement	Concrete surface layer	26	30	*	*	10	40
	Hydraulically bound base layer	55	70	*	*		
	Asphalt concrete base layer	50	65	*	*		
	Unbound base layer	45	60	*	*		
Maintenance materials	Slurry surfacing	6	8	–	–	8	–
	Micro-surfacing	5	8	–	–		
	Thin HMA layer on sealing	8	10	–	–		

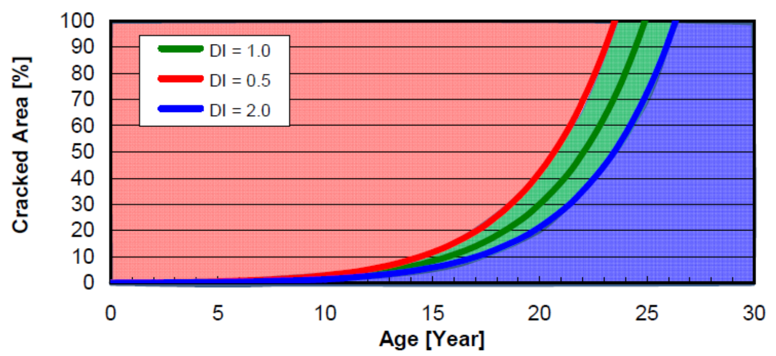
* Highway maintenance in the Netherlands aims at timely strengthening the asphalt base layers and (sub)bases and thus, never has to be replaced.

In the project InteMat4PMS: *Integration of material-science based performance models into life-cycle analysis processed in the frame of pavement management systems* (ERA-Net II research project), Wistuba *et al.* (2013) highlighted that the realistic prediction of pavement performance over long time periods is of vital importance for effective assessment of maintenance options within the PMS. Prediction quality depends on the prediction model of pavement performance and input data. Performance prediction is realized by extrapolating pavement condition development into the future, based on what has been observed in the past. This is typically called the empirical approach, and the so-developed mathematical performance functions are called empirical performance functions (EPFs).

Realistic performance modelling is especially needed for decision processes at project level, which require a higher level of accuracy in comparison to more general considerations at network level. Material and structural pavement properties can potentially be taken into account to improve the performance prediction assumptions of the EPF for fatigue. As a result, a new performance function (called 'Laboratory Calibrated EPF'), can be derived.

In InteMat4PMS, the applicability of the new analysis procedure based on Laboratory Calibrated EPF has been tested in different case studies (for two test sections), focusing on fatigue failure and pavement cracking mechanisms, and considering three different performance prediction models with different initial EPFs (documented in the German PMS, the Austrian PMS, and in HDM-4) described below:

- The Austrian prediction model (Figure 26) is derived from regression analysis of condition data and describes pavement cracking deterioration in function of the surface layer age, the design index DI and a material specific coefficient.



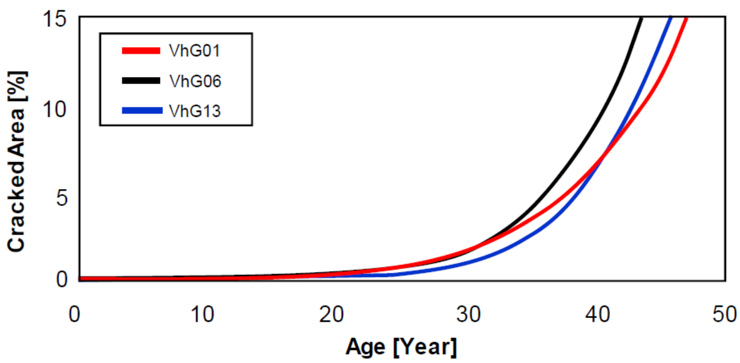
DI ≤ 0.5 for under-designed pavement;

0.5 < DI < 2 for properly designed pavement;

DI ≥ 2 for over-designed pavement)

Figure 26: Austrian cracking prediction model for motorways and expressways (Molzer *et al.*, 2002).

- The German prediction model displays alligator-cracking in function of cumulative 10-tons-ESALs and of specific coefficients for the pavement type (new or already rehabilitated).



heavy loaded asphalt pavement

VhG01: asphalt concrete wearing course design index < 0.8

VhG06: mastics asphalt wearing course design index < 0.8

VhG13: cement stabilized base course design index >= 0.8

Figure 27: German cracking prediction model for 3 different pavement categories (acc. Hinsch *et al.*, 2005).

- The HDM-4 cracking model is a complex time-based model, which distinguishes initiation and propagation phases of different types of cracks, such as structural cracks, reflective cracks, and thermal cracks. Structural cracking is modelled based, inter alia, on information on pavement design (structural number, bearing capacities), layers (materials, thickness), construction defects (binder content), number of ESALs, crack retardation time due to maintenance (years), and incremental change in area of cracking during the analysis year (%).

The analysis of the case studies shows that most of the performance prediction models can be applied on a high percentage of the network and for different types of pavements, but they are too general for an accurate prediction at project level. The consequence of this inaccuracy is a high variation in the prediction of future maintenance needs (Table 26). All three models (German, Austrian, HDM-4) show a high degree of variance in the results if only section-specific first-level calibration is performed. If a second step of calibration is integrated by means of a Laboratory Calibrated EPF, the real pavement performance model is significantly improved.

Table 26: Results of the performance prediction model used in the LCA (Wistuba *et al.*, 2013).

	Performance prediction model		
	Austrian model	**German model**	**HDM-4 model**
Test Section 1			
Year of 1st major treatment	20	>40	11
Type of 1st major treatment	Reinforcement	Reconstruction	Replacement of wearing and binder course
Test Section 2			
Year of 1st major treatment	17	>40	9
Type of 1st major treatment	Reinforcement	Reconstruction	Replacement of wearing and binder course

To sum up, a more precise definition of durability can now be provided, based on the EARN (Nicholls *et al.*, 2014) and the InteMat4PMS (Wistuba *et al.*, 2013) projects. With reference to the outcomes of these projects, it seems reasonable to set a common minimum durability expressed as nominal service lifetime of the pavement that could be applied to different types of roads. **The nominal service lifetime is a design parameter set in the performance prediction model of a pavement to define the design lifetime during which any structural maintenance or rehabilitation activity is not required**. It has to be highlighted that the service lifetime will be further analysed by means of the PMS (for example applying a Laboratory Calibrated EPF) and updated in the M&R strategies plan, in order to better specify real maintenance needs.

Additional examples of requirements on the nominal service lifetime have been found in literature. For example, draft technical specifications on durability of flexible pavement are currently under discussion by the Italian Ministry of Environment. These technical specifications will likely be formulated as minimum serviceability of surface course (5 years), binder and base courses (10 years) and sub-base course (40 years) for secondary roads. It is also proposed to award points for service lifetime of the pavement of at least 20 years for the binder and base courses and 60 years for the sub-base course.

Similar durability requirements are defined within the 'Perpetual pavement' concept introduced in 2000 in the US by the Asphalt Pavement Alliance (APA). They defined a Perpetual Pavement as *an asphalt pavement designed and built to last longer than 50 years without requiring major structural rehabilitation or reconstruction, and needing only periodic surface renewal in response to distresses confined to the top of the pavement* (APA, 2002). The advantages of such pavements include:

- Low life-cycle cost by avoiding deep pavement repairs or reconstruction;
- Low user-delay costs since minor surface rehabilitation of asphalt pavements only requires short work windows that can avoid peak traffic hours; and
- Low environmental impact by reducing the amount of material resources, including the recycled materials, over the pavement's life cycle.

Regardless of the structural integrity of the pavement, preventive resurfacing generally needs to occur within 20 years to improve friction, reduce noise, and mitigate surface cracking (APA, 2010). The durability proposed by the 'Perpetual pavement' project seems in line with the draft award criterion under discussion in the framework of the Italian GPP criteria for road construction.

A relevant US project addressing the durability of asphalt pavements is Superpave which stands for SUperior PERforming Asphalt PAVEments (SUPERPAVE). Superpave consists of three basic components:

- Asphalt binder specification;
- Design and analysis system based on the volumetric properties of the asphalt mix;
- Mix analysis tests and performance prediction models on durability of the pavement.

However, the information available on the SUPERPAVE project didn't contain any benchmark to be used for setting the durability criterion.

According to the ELLPAG project (FEHRL, 2004), a long-life pavement is a type of pavement where no significant deterioration will develop in the foundations or the road base courses provided that correct surface maintenance is carried out (deterioration *includes whatever the network manager considers important, e.g., significant cracking or (progressive) deformation in the structural layers of a fully flexible pavement; for other types of pavement, 'deterioration' could be quite different*) Long-life pavements are therefore expected to experience deterioration in the surfacing rather than structural deterioration deeper in the pavement. With reference to the ELLPAG consultation on long-life fully-flexible pavements and/or fully-flexible pavements designed for heavy traffic, the majority of European design methods use a maximum design period of 20 years without any structural maintenance requirements. Some countries are adopting longer design periods, for example in France, the nominal design lifetime is 30 years. However, economic analysis is usually carried out over more than 30 years (often 40 years on privately run motorways). In the Netherlands, fully-flexible pavements are designed for an initial 20 year period. These pavements can be overlaid so that in practice they never reach a structural failure condition. The design period of flexible pavements in the UK is either 20 or 40 years. Provided that these pavements are well constructed, fully-flexible pavements designed for 40 years and for traffic in excess of 80 msa_{80} (MSa_{80}=80 kN million standard axles), should be considered long-life pavements. A design period is not defined for flexible pavements in the German pavement design method; instead there is a "useful life" of 20 years, which sets the date to which the daily traffic is projected and does not determine the cumulative number of loads that will be applied to the structure. One stakeholder suggested that in some PPP contracts in Germany, this design parameters is set at 30 years.

Table 27 shows the nominal service lifetimes (design periods) for the maximum levels of design traffic within the national design method declared in the ELLPAG questionnaire responses. As can be observed, the most common nominal service lifetime is 20 - 30 years regardless of the variation of the maximum design traffic, while 40 years and 10 years are set as design parameters for some particular cases. It is important to highlight that the actual Annual Average daily Traffic (AADT) values that correspond to the maximum standard axle load values do not show such wide variation, since they are very dependent on the defined characteristic vehicles used by each national design method (France maximum design traffic 210 msa_{100} over a 30 years period is equal to 10000 vehicles per day and Belgium maximum design traffic 128 msa_{100} over 20 years is equal to 8000 vehicles per day).

Table 27: Stated Maximum Design Traffic in each country (FEHRL, 2004).

	Reference Standard Axle (kN)	Maximum Design Traffic (msa)	Highest Traffic Category (msa_{100})	Design Period (years)
Austria	100	25	25	20
Belgium	100	128	128	20
Denmark	100	5.5	5.5	10
Finland	100	10	10	20
France	130	75	215	30
Germany	100	>32	>32	30
Greece	130	44	126	20
Hungary	100	22	22	20
Italy	80	68	28	20
Norway	100	10	10	20
Poland	100	15	15	20
Sweden	100	19	19	20
Switzerland	80	73	30	20
USA	80	200	82	40
UK	80	500*	205	40
Netherlands	100	-	-	20

* The design curve is truncated at 80msa_{80} but extends up to 500msa_{80}.

Based on the rationale above, the ageing effects on the road can be monitored during the operation phase. However, ex-ante criteria aimed at selecting the most appropriate design in terms of durability of the road pavement would lead to an optimized maintenance strategy.

Additional data on the service lifetime has been collected from experts in the construction sector. With reference to the LCC of different pavement alternatives, the following lifetime for maintenance activities of surface courses has been suggested: 9 years for PA, 12-13 years for asphalt concrete and very thin asphalt concrete and 15 years for SMA.

For rehabilitation, the following lifetimes have been suggested: 24-26 years for asphalt concrete and very thin asphalt concrete, 27 years for PA and 30-36 years for SMA. These preliminary data are currently being analysed in the DurabRoads[38] EU FP7 project, whose main objective is to contribute towards sustainable

38 http://www.durabroads.eu/

growth through the development and demonstration of cost-effective, eco-friendly, durable and resilient pavements.

With reference to some German PPP contracts, the following minimum nominal service lifetimes have been provided for different pavement courses: 16 years for SMA surface course, 26 years for asphalt binder and 55 years for asphalt base course.

Considering the analysed literature and the feedback received after the 2nd AHWG, the following considerations are proposed:

- The nominal service lifetime for surface courses shows a huge variability depending on different factors, such as climate conditions, traffic intensity and pavement materials (see Table 25, EARN project and data provided in the LCC analysis in section 3 and the above-mentioned data provided by experts in the sector), therefore it does not seem realistic to set a general minimum requirement for the surface course that could apply in different conditions. However, in order to take into consideration the different local practices and conditions, stakeholders highlighted that the contracting authority may specify a minimum nominal service lifetime for the surface course if the specific conditions of the road pavement allow setting a threshold.
- With reference to the EARN project and to the data provided in the LCC analysis in section 3.3 and data provided by experts in the sector, it appears to be possible to set requirements for the binder course of flexible pavements. According to expert feedback, a nominal service lifetime of 15 years is feasible, even though the option to reduce this lifetime to 10 years in specific aggressive conditions or to extend it to 20 years in more ambitious solutions should be allowed.
- The main requirement specification appears to be related to the structural maintenance activities (rehabilitation) on the base course for flexible pavements and on the slabs for rigid pavements. According to OECD (2005), a service lifetime of 20 years for the core criteria and 40 years for the comprehensive criteria can be proposed for both flexible and semi-rigid pavements and for rigid pavements (see Table 19). Similar results are also shown in the EARN project (see Table 25). Moreover, according to the ELLPAG project, the majority of European design methods use a maximum design period of 20 years without any structural maintenance requirements. According to expert feedback and specific MS experience, a nominal service lifetime of 40 years can be set for more ambitious solutions.
- Finally, according to the EARN, 'Perpetual pavement' US project and to the data provided in the LCC analysis (see section 3.3), it seems also possible to set a requirement for the sub-base course from 40 to 60 years.

In conclusion, the final criterion proposal on the pavement durability is performance-based, focusing on the nominal service lifetime set in the pavement design:

- The nominal service lifetime of the road pavement, excluding the surface layer, shall be as specified by the contracting authority. Additionally, the contracting authority may specify a minimum nominal service lifetime for the surface course if the specific conditions of the road pavement allow setting a threshold.
- For the core criterion, the nominal service lifetime shall be, as a minimum, equal to 15 years for the binder course (with the option to reduce to no less than 10 years in case of specific conditions), 20 years for the base course for flexible/semi-rigid pavements and for the concrete slab for rigid pavements, and 40 years for the sub-base course.
- For the comprehensive criterion, the nominal service lifetime shall be, as a minimum, equal to 20 years for the binder course (with the option to reduce to no less than 15 years in case of specific conditions), 40 years for the base course for flexible/semi-rigid pavements and for the concrete slab for rigid pavements, and 60 years for the sub-base course.
- It seems more appropriate to set these requirements as a technical specification. All the lifetime extension with rehabilitation activities will be described in the maintenance and rehabilitation strategies plan and will be taken into consideration within the CF/LCA award criteria.

2.8.1.2 Summary of feedback from the 2nd round consultation of stakeholders

Stakeholder feedback received after the 2nd AHWG
The main comments received from stakeholders during the 2nd AHWG meeting and the 2nd round of consultation can be summarised as follows: - *A better description of the concept of pavement durability should be provided.* - *The nominal service lifetime should be decided by the contracting authority* in order to account for the individual approaches of each MS, which are based on local experiences and practices. Therefore, only a minimum nominal value shall be proposed. - *The surface course durability requirements should be excluded from the criterion*, because its durability is strongly affected by climate conditions, traffic intensity and pavement materials and thus it is not possible to set generic requirements that could apply to all kind of pavements and conditions. It has been suggested to set the durability criterion for the binder, base and sub-base courses, which have a long durability and to account for surface courses in the M&R Plan criterion. On the contrary, other stakeholders underlined that excluding the surface course durability in the durability criterion is not a performance-based approach and that a specific performance that could be fulfilled by different solutions should be identified, because different materials should compete on those requirements. Considering rigid pavement performance, it was suggested that a minimum nominal service lifetime for the surface course could be 15 years as a core criterion and 30 years as a comprehensive criterion. - *Avoid any distinction in ambition levels for different materials and pavement typologies.* - *Provide more ambitious minimum performances for the comprehensive criteria*. - *Consider (forecast) the synergistic effect of traffic and environmental loads,* especially in the countries with extreme climatic conditions.

2.8.1.3 Final criteria proposal

Core criteria	**Comprehensive criteria**
TECHNICAL SPECIFICATIONS	
B11. Performance requirements for durability of pavement	**B11. Performance requirements for durability of pavement**
The nominal minimum service lifetime of the road pavement, excluding the surface course, shall be specified by the contracting authority but should not be shorter than: - 15 years for the binder course, with the option to reduce to no less than 10 years in case of specific conditions (such as an aggressive climate - *to be specified in the ITT*); - 20 years for the base course for flexible/semi-rigid pavements and for the concrete slab for rigid pavements; - 40 years for the sub-base.	The nominal minimum service lifetime of the road pavement, excluding the surface course, shall be specified by the contracting authority but should not be shorter than: - 20 years for the binder course with the option to reduce to no less than 15 years in case of specific conditions (such as an aggressive climate - *to be specified in the ITT*); - 40 years for the base course for flexible/semi-rigid pavements and for the concrete slab for rigid pavements; - 60 years for the sub-base.
Additionally the contracting authority may specify a minimum nominal service lifetime for the surface course if the specific conditions of the road pavement allow setting a threshold.	*Additionally the contracting authority may specify a minimum nominal service lifetime for the surface course if the specific conditions of the road pavement allow setting a threshold.*
Verification:	**Verification:**
The design team *or* the DB tenderer *or* the DBO tenderer shall provide a technical report specifying the minimum nominal service lifetime of the binder and base courses and the sub-base course, which must not be shorter than indicated above. The report shall include the evaluation of	The design team *or* the DB tenderer *or* the DBO tenderer shall provide a technical report specifying the minimum nominal service lifetime of the binder and base courses and the sub-base course, which must not be shorter than indicated above. The report shall include the evaluation of

the bearing capacity and the fatigue resistance, and the critical stresses and strains in the road pavement layers. The report shall include appropriate data and information, specifically related to: the physico-mechanical performance of materials, the construction techniques and processes used, and the construction activity workplan.	the bearing capacity and the fatigue resistance, and the critical stresses and strains in the road pavement layers. The report shall include appropriate data and information, specifically related to: the physico-mechanical performance of materials, the construction techniques and processes used, and the construction activity workplan.
CONTRACT PERFORMANCE CLAUSES	
Please refer to the general contract performance clause C1 Commissioning of the road construction	Please refer to the general contract performance clause C1 Commissioning of the road construction
Please refer to the general contract performance clause E4 Commissioning of the road maintenance	Please refer to the general contract performance clause E4 Commissioning of the road maintenance

Summary rationale for the final criteria proposal:

- The deterioration rate of materials, dependent on their mechanical and chemical properties, together with the appropriate design and construction of the road, are the factors with the biggest influence on the service life of the road and its needs for maintenance.
- The most durable materials might entail higher construction costs, but those expenses could be offset by means of less demand of maintenance.
- The ageing effects of the road can be monitored during the operation phase, but ex-ante criteria aimed at selecting the most appropriate design in terms of durability of the road surface and structure would lead to an optimized maintenance strategy.

2.8.1.4 At what stage of the procurement process are the criteria relevant?

The criteria classification, their reference numbers in the criteria document and the respective procurement phase can be cross-referenced as follows.

Title of the criterion	Procurement phase	Criterion classification	Criteria typology	Reference number in the criteria document
Performance requirements for durability of pavement	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B11
Commissioning of the road construction	C. Construction	Core and Comprehensive	Contract performance clause	C1
Commissioning of the road maintenance	E. Maintenance and operation	Core and Comprehensive	Contract performance clause	E4

2.8.2 Maintenance and Rehabilitation Strategy Plan

2.8.2.1 Background technical discussion and rationale for Maintenance and Rehabilitation Strategy Plan

The maintenance of the road network has become a highly important part of road management since many environmental impacts identified are related to this phase. For example, maintenance activities are implemented to mitigate the noise due to damaged pavement, but they also might cause traffic congestion. The road network in Europe is quite well developed, and preservation of the asset must be secured.

The objectives of maintenance are to maintain or restore the road network condition to counterbalance its deterioration due to weather, traffic, aging *etc*... The results of maintenance actions must be measured to assess its effectiveness, *i.e.*, the degree to which its objectives are achieved. In addition, the maintenance activities should be planned and scheduled in time so that congestion can be minimized.

Maintenance and maintenance objectives

Road maintenance includes multiple and overlapping activities. It is challenging to find a universal definition and classification that could apply across Europe. In order to be consistent with the terminology used throughout Europe, and following the suggestions of some stakeholders received during the consultation after the 2nd AHWG meeting, the BEXPRAC study (CEDR, 2010a) is taken as a reference. This study was carried out by 13 NRAs in order to benchmark the performance of their maintenance and operation policies within the framework of the Conference of European Directors of Roads (CEDR). Taking into consideration the homogeneous way of defining life cycle cost actions introduced in this study, the following definitions are proposed:

Road maintenance: *all actions undertaken to maintain and restore the serviceability and level of service of roads* (PIARC Road Dictionary).

- *Routine maintenance: all operations which can be scheduled on a periodical basis with a view to maintaining a satisfactory level of service which is as close as possible to the initial state and in accordance with the classification of the road* (PIARC Road Dictionary).
- *Preventive maintenance and rehabilitation: work undertaken to* preserve or *restore serviceability and to extend the service life of an existing* road (PIARC Road Dictionary).

  Preventive maintenance is typically applied to pavements in good condition having significant remaining service life, without significantly altering the structural capacity, while rehabilitation takes place when the structural efficiency of the existing facility is compromised.

Road reconstruction: *work performed to upgrade the network or replace* the entire road section (CEDR 2013). From a procurement perspective, this phase is similar to the construction phase and therefore would be subject to a specific ITT.

Condition and Performance Indicators

For the characterization of the condition or functionality of a sub-asset's performance or of a component's performance, indicators that describe the different characteristics in a balanced way should be used. The selection of adequate performance indicators is strongly dependent on the type of asset.

The following list is a general recommendation of indicators which should be taken into consideration for the assessment of road infrastructure (Weninger-Vycudil, 2009):

- Performance indicators for pavements according to the COST 354 Report "Performance Indicators for Road Pavements" (COST, 2008):
  - User-related single performance indicators to describe the safety and the comfort of the pavement:
    - Skid resistance / texture;
    - Rutting;
    - Longitudinal evenness.
  - Structure-related single performance indicators to describe the structural (technical) status of the pavements:
    - Cracking;
    - Other structural defects (ravelling, bleeding, *etc.*);
    - Bearing capacity.
  - Environment-related indicators to describe at least the noise emission;
  - Combined performance indicators for:
    - Safety;
    - Comfort;
    - Structure;
    - Environment;
    - General performance indicator to describe the overall condition of the pavement.

- Performance indicators for structures:
  - Component-specific single performance indicators to describe the distresses as follows:
    - Type;
    - Extent;

        - Severity.
    - Combined performance indicators to describe the following characteristics of the structures:
        - Stability;
        - Safety;
        - Durability.
    - General performance indicator to describe the overall condition of the structure.

Monitoring and data acquisition

Subject to the different types of sub-assets, the following investigations are recommended (Weninger-Vycudil, 2009):

- Pavements:
    - Measurements for user specific performance indicators (skid resistance /texture, rutting, longitudinal evenness), bearing capacity and environmental indicators (noise emission);
    - Visual inspections in combination with video-systems or images for structural performance indicators (cracking and other surface defects).

- Structures:
    - Visual inspection of sub-components with video- or image documentation.

In addition, this study also recommends that the intervals of monitoring coincide with the local requirements and the given national and/or European standards. The following values are recommended as the maximum intervals of measurement and visual inspections on network level:

- Pavements: max. 5 years.
- Structures: max. 6 years.

Additional information needed to find the optimum maintenance strategy of a certain sub-asset or component is also recommended to be collected, updated and checked in a certain interval. This information comprises:

- Inventory data (extent of assets, location and reference, construction types, maintenance history, *etc.*);
- Input parameter for the definition of the maintenance objectives which are in line with the performance indicators in use (threshold values, percentages of condition classes, *etc.*);
- Input parameter for finding the optimum maintenance strategy based on LCC analysis (cost, triggers, performance prediction models, economic parameters, *etc.*).

According to Sjögren *et al.* (2012, He-road project), a road asset management is a holistic approach that integrates the strategic and systematic process of operating, maintaining, upgrading and expanding physical assets effectively throughout their life cycle. A road asset management includes pre-investigation, planning, design, construction, daily operations, planned maintenance, improvement and decisions on re-cycling or removal (Figure 28). Furthermore the road user perspective has become a target area to be considered. Figure 28 shows the indicators identified in the HeRoad report *Overall road asset performance* by Sjögren *et al.* (2012) as those parameters actually used in the routine work. According to this report, the details in the strategic level are the common goals found in most countries, regions in the EU. Lower levels as functional and operational levels may differ much more between countries and regions. The figures try to link the technical parameters to upper level (strategically) indicators.

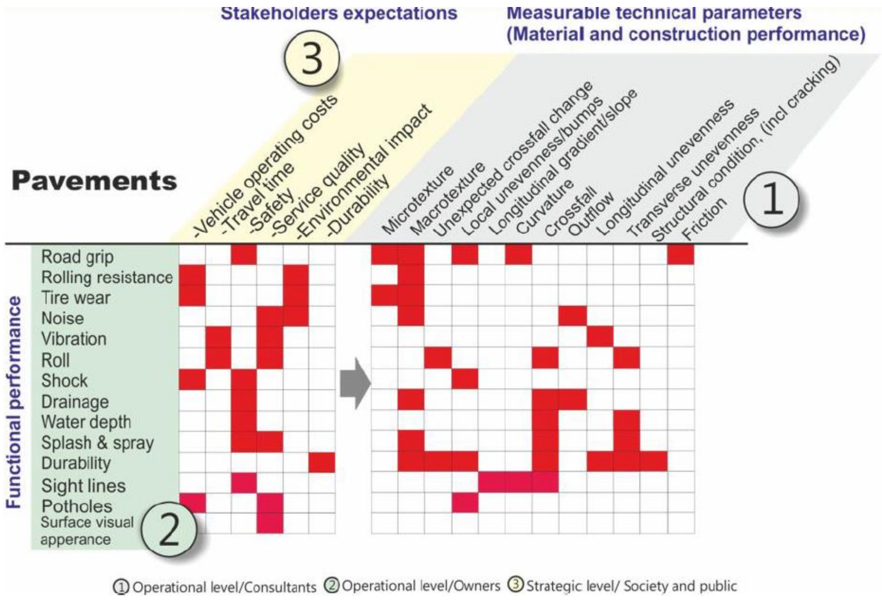


Figure 28: Pavement technical parameters (Sjögren *et al.*, 2012).

Maintenance Standard / Maintenance Goals

The main objectives to be achieved by maintenance activities must be expressed by parameters which are in in line with the performance indicators in use. The following are suggested by Weninger-Vycudil (2009):

- Threshold values which define the border line between fulfilled and unfulfilled demands (*e.g.*, in form of a condition-related value or a maximum deterioration rate);
- Thresholds values which define the lowest acceptable condition (*e.g.*, in form a condition-related value or a maximum deterioration rate);
- Target values which define the optimum condition to be achieved after maintenance measures (*e.g.*, in form of a condition-related value);
- Percentage of condition classes or ranges to be achieved (in case of given condition distribution standards).

These values are related to functional and structural requirements and are laid down in the respective national guidelines or manuals. Ideally they are derived from an analytical relationship between the indicator and the consequences to the road user, but in most cases they are adapted in some way to the given or accepted condition distribution at the network and the related risk assessment (*e.g.*, traffic accidents).

Especially for pavements and structures, these input parameters are widely available; *e.g.*, COST 354 Report "Performance Indicators for Road Pavements" (COST, 2008) provides a selection of performance parameters and transfer functions that enables to grade the road based on their main parameters, and thus, to establish thresholds aimed at a systematic monitoring and maintenance.

In the view of the above information, a maintenance strategy should be structured in several dimensions:

- The main parameters must be defined, as well as proper monitoring, data acquisition method and threshold values that correlate with the maintenance actions. This dimension of the maintenance strategy could be depicted by the following table:

Performance parameter	Monitoring frequency	Acceptance threshold	Warning threshold	Action threshold	Maintenance action
Unevenness					
Rutting					
Other structural defects (ravelling, bleeding, etc.)					
Bearing capacity					
Texture (optional)					
Noise (optional)					

For those parameters that affect safety conditions, service quality and durability, the frequency of monitoring and the threshold values should be defined by the Road Authorities, in line with their legal requirements. The thresholds for MPD and noise should be in line with the bid of the tenderer (when the proposed award criteria have been used).

- Maintenance actions should be planned in advance, defining methods, frequency, amount and cost of the maintenance and rehabilitation activities, for each section of road specifically characterised by specific construction methods, materials, environmental conditions, meteorological conditions and use. The maintenance plan should also be consistently linked to the performance parameters defined in the table above and the congestion mitigation plan set by the criterion.

	Cost	**First year**	**Frequency**	**Performance parameters affected**	**Congestion mitigation plan**
Routine maintenance					
Periodic					
Rehabilitation					

Pavement Management System (PMS)

The recommended maintenance and rehabilitation actions are determined, in most countries, by using a pavement management system (PMS), *i.e.*, a planning tool to aid pavement management decisions. PMS software programs model future pavement deterioration due to traffic and weather, and to the road's pavement based on the type and age of the pavement and various measures of existing pavement quality. Measurements can be made by people on the ground, visually from a moving vehicle, or using automated sensors mounted to a vehicle. PMS software often helps the user create composite pavement quality rankings based on pavement quality measures on roads or road sections. Recommendations usually favour preventive maintenance, rather than allowing a road to deteriorate until it needs more extensive reconstruction.

During the 2nd AHWG meeting, it has been underlined that the monitoring plan is not set by the contractors, but instead decided by the NRA/local authorities based on a reference monitoring plan. Therefore, the monitoring plan has been deleted as a performance requirement in the design phase. Furthermore, based on the feedback received during the 2nd round of consultation, the core criteria are now proposed with a more general character for separate Design and Built contracts and DB contract, while a more specific approach has been required for DBO contracts. The comprehensive criteria have a more detailed character and have not changed from the previous proposal.

2.8.2.2 Summary of feedback from the 2nd round consultation of stakeholders

Stakeholder feedback received after the 2nd AHWG meeting

- The monitoring plan is not set by the contractors, but instead decided by the NRA/local authorities based on a reference monitoring plan. However, contractors could be asked to provide an improved monitoring plan.
- An NRA expert suggested that the surface courses maintenance has to be included in the M&R Plan. This same expert also underlined the importance of the CF or LCA criteria, in which maintenance and rehabilitation are already included.
- In most MSs, NRAs have to specify the maintenance needs in a reference M&R Plan. In the Netherlands, for example, a reference maintenance plan is drafted by the NRA and the contractor has to calculate and declare the environmental impacts (or CF) of each maintenance step according to the maintenance intervals set by the NRA. However, in some contracts such as DBO, the contractor might have to provide the (average) maintenance intervals, declare the environmental impacts and propose an improved maintenance plan, if needed. Finally, if during the monitoring phase, maintenance intervals deviate from those declared during the design phase, a penalty system applies.

2.8.2.3 Final criteria proposal

Core criteria	Comprehensive criteria
TECHNICAL SPECIFICATIONS	
B12. Maintenance and Rehabilitation (M&R) Plan **OPTION 1** *(This option applies in case of DBO contracts)* The DBO tenderer shall include a M&R Plan in the detailed design. For each section of road characterised by specific construction methods, materials, environmental conditions, meteorological conditions and use, the M&R Plan shall, as a minimum: - Include routine, preventive and rehabilitation actions; - Optimise the cost-benefit ratio of the maintenance works; - Declare the environmental performance of any routine, preventive and rehabilitation action/strategy that have been included in the CF (according to the criterion B14 if applicable); - Include the cost, expected intervals between maintenance activities, the Traffic Congestion Mitigation Plan (according to the criterion B10) and the Demolition Waste Management Plan (according criterion E2) for each action.	**B12. Maintenance and Rehabilitation (M&R) Plan** The design team *or* the DB tenderer *or* the DBO tenderer shall include a M&R Plan in the detailed design. For each section of road specifically characterised by specific construction methods, materials, environmental conditions, meteorological conditions and use, the M&R Plan shall, as a minimum: - Include routine, preventive and rehabilitation actions; - Optimise the cost-benefit ratio of the maintenance works; - Declare the environmental performance of any routine, preventive and rehabilitation action/strategy that have been included in the LCA (according to the criterion B14 if applicable); - Include the cost, expected intervals between maintenance activities, the Traffic Congestion Mitigation Plan (according to the criterion B10) and the Demolition Waste Management Plan (according criterion E2) for each action. **Verification:** The Design team *or* DB tenderer *or* DBO tenderer shall provide a technical report including appropriate data and information and the design activities workplan.
OPTION 2 *(This option applies in case of separate Design and Build contracts or DB contracts)* The design team *or* DB tenderer shall include in the detailed design a global M&R Plan. For each section of road characterised by specific construction methods, materials, environmental conditions, meteorological conditions and use, the global M&R Plan shall include: - the environmental performance of the routine, preventive and rehabilitation actions (according to the criterion B14 CF if applicable); - the average intervals of all routine, preventive and rehabilitation actions (if it is not set by the contracting authority); - the Traffic Congestion Mitigation Plan (according to the criterion B10) and the Demolition Waste Management Plan (according criterion E2) for each action.	
Verification: The Design team *or* the DB tenderer *or* the DBO tenderer shall provide a technical report including appropriate data and information and the design activities workplan.	
CONTRACT PERFORMANCE CLAUSES	
D3 Commissioning of the Maintenance and Rehabilitation (M&R) Plan *(This option applies in case of DBO contracts, where*	**D3. Commissioning of the Maintenance and Rehabilitation (M&R) Plan** *(This option applies in case of DBO contracts, where*

monitoring is carried out by the DBO contractor) The DBO contractor shall, case a significant deviation from the M&R Plan proposed in the design phase is considered necessary, inform the contracting and agree, if justified, upon any deviation.	*monitoring is carried out by the DBO contractor)* The DBO contractor shall, case a significant deviation from the M&R Plan proposed in the design phase is considered necessary, inform the contracting authority and agree, if justified, upon any deviation.
E3. Commissioning of the Maintenance and Rehabilitation (M&R) Plan The main construction contractor *or* the DB contractor *or* the DBO contractor shall commit to maintain the road according to the M&R Plan (see criterion B12).	**E3. Commissioning of the Maintenance and Rehabilitation (M&R) Plan** The main construction contractor *or* the DB contractor *or* the DBO contractor shall commit to maintain the road according to the M&R Plan (see criterion B12).
Please refer to the general contract performance clause E4 Commissioning of the road maintenance.	Please refer to the general contract performance clause E4 Commissioning of the road maintenance.

Summary rationale for the final criteria proposal:

- It is widely agreed that the maintenance of the road network is a relevant part of the road management and many proposed criteria, and their associated environmental impacts, are related to this phase (rolling resistance, noise, congestion, durability).
- The results of the maintenance actions must be measured to assess its effectiveness, *i.e.*, the degree to which its objectives are achieved. In addition, the maintenance activities should be planned and scheduled in time so congestion can be minimized.
- The maintenance strategy needs to be structured by means of a maintenance plan that describes the actions to be taken along the service life of the road.

2.8.2.4 At what stage of the procurement process are the criteria relevant?

The evaluation of the traffic flow expected in the road, and particularly, the expected heavy traffic, together with the congestion that might be derived from the maintenance plan, shall be defined in the preliminary scoping and feasibility (establishing environmental performance objectives) in order to inform the maintenance strategy.

Pavement performance assessment and monitoring and verification of the performance parameters shall be performed in the *use phase*. Maintenance activities have to be realised according to the M&R Plan in the *maintenance and operation phase*, taking into account the target values of the performance parameters in the detailed design.

An M&R Plan should be presented. This plan can be used as a baseline and shall be updated by the DBO tenderer or the tenderer appointed for the maintenance works on the base of the results of the pavement performance assessment and verification. Moreover, new, more durable materials, new technologies and best available maintenance strategies should be analysed while updating the M&R Plan.

The criteria classification, their reference numbers in the criteria document and the respective procurement phase can be cross-referenced as follows:

Title of the criterion	Procurement phase	Criterion classification	Criteria typology	Reference number in the criteria document
Maintenance and Rehabilitation (M&R) Plan	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B12
Commissioning of the Maintenance and Rehabilitation (M&R) Plan	D. Use	Core and Comprehensive	Technical specification	D3
Commissioning of the Maintenance and Rehabilitation (M&R) Plan	E. Maintenance and operation	Core and Comprehensive	Technical specification	E3
Commissioning of the road maintenance	E. Maintenance and operation	Core and Comprehensive	Contract performance clause	E4

2.9 General contract performance clauses

In order to simplify the readability of the criteria proposal, a general contract clause is proposed both for the construction and the maintenance phases as follows:

<table>
<tr><th colspan="2">CONTRACT PERFORMANCE CLAUSES</th></tr>
<tr>
<td>C1. Commissioning of the road construction
The main construction contractor or the DB constructor or the DBO contractor has to ensure that the commissioning of the road construction conforms to the agreed designs and specifications. Particular attention should be paid to the following aspects:
- CF/LCA performance of the main road elements (criterion B14) or the CO_2 emissions per tonne of transported materials (criterion B16);
- Excavated Materials and Soil Management Plan (criterion B2);
- Water pollution control components, stormwater retention capacity and Environmental Integration and Restoration Plan and wildlife passage design in the drainage system (criteria B3, B4, B5, B17, B18, B19);
- Pavement durability (criterion B11);
- Traffic Congestion Mitigation Plan implementation (criterion B10).
The main construction contractor or the DB constructor or the DBO contractor shall, in case a significant deviation from the design requirements during the construction phase is considered necessary, inform the contracting authority and agree, if justified, upon any deviation.
For cases where no agreement is reached, the contract clauses should lay down a pre-determined procedure for deciding upon appropriate and proportional penalties for non-compliance and/or remedial or mitigation actions.</td>
<td>C1. Commissioning of the road construction
The main construction contractor or the DB constructor or the DBO contractor has to ensure that the commissioning of the road construction conforms to the agreed designs and specifications. Particular attention should be paid to the following aspects:
- pavement macrotexture (MPD) (see criterion B13);
- CF/LCA performance of the main road elements (criterion B14) or the CO_2 emissions per tonne of transported materials (criterion B16);
- Excavated Materials and Soil Management Plan (criterion B2);
- Water pollution control components, stormwater retention capacity and Environmental Integration and Restoration Plan and wildlife passage design in the drainage system (criteria B3, B4, B5, B17, B18, B19);
- Pavement durability (criterion B11);
- Traffic Congestion Mitigation Plan implementation (criterion B10).
The main construction contractor or the DB constructor or the DBO contractor shall, in case a significant deviation from the design requirements during the construction phase is considered necessary, inform the contracting authority and agree, if justified, upon any deviation.
For cases where no agreement is reached, the contract clauses should lay down a pre-determined procedure for deciding upon appropriate and proportional penalties for non-compliance and/or remedial or mitigation actions.</td>
</tr>
<tr><th colspan="2">CONTRACT PERFORMANCE CLAUSES</th></tr>
<tr>
<td>E4. Commissioning of the road maintenance
The main maintenance contractor or the DB constructor or the DBO contractor has to ensure that the commissioning of the road maintenance conforms to the agreed designs and specifications. Particular attention should be paid to the following aspects:
– CF/LCA performance of the main road elements (criterion B14) or the CO_2 emissions per tonne of transported materials (criterion B16);
– Water pollution control components, stormwater retention capacity and Environmental Integration and Restoration Plan and wildlife passage design in the drainage system (criteria B3, B4, B5, B17, B18, B19);
– Pavement durability (criterion B11);
– Traffic Congestion Mitigation Plan implementation (criterion B10).
The main construction contractor or the DB constructor or the DBO contractor shall, in case of a significant deviation from the design requirements during the construction phase is considered necessary, inform the contracting authority and agree, if justified, upon any deviation.
In cases where no agreement is reached, the contracting authority should have in place a decision tree for deciding upon appropriate and proportional penalties for non-compliance and/or remedial or mitigation actions.</td>
<td>E4. Commissioning of the road maintenance
The main maintenance contractor or the DB constructor or the DBO contractor has to ensure that the commissioning of the road maintenance conforms to the agreed designs and specifications. Particular attention should be paid to the following aspects:
– pavement macrotexture (MPD) (see criterion B13);
– CF/LCA performance of the main road elements (criterion B14) or the CO_2 emissions per tonne of transported materials (criterion B16);
– Water pollution control components, stormwater retention capacity and Environmental Integration and Restoration Plan and wildlife passage design in the drainage system (criteria B3, B4, B5, B17, B18, B19);
– Pavement durability (criterion B11);
– Traffic Congestion Mitigation Plan implementation (criterion B10).
The main construction contractor or the DB constructor or the DBO contractor shall, in case of a significant deviation from the design requirements during the construction phase is considered necessary, inform the contracting authority and agree, if justified, upon any deviation.
In cases where no agreement is reached, the contracting authority should have in place a decision tree for deciding upon appropriate and proportional penalties for non-compliance and/or remedial or mitigation actions.</td>
</tr>
</table>

2.10 Conclusions

The use of the GPP criteria is voluntary, and each contracting authority should choose, depending on its experience and ambition, which of the GPP criteria it wants to integrate in its tender. Attention should be paid to the fact that not all criteria are relevant for all roads, see Table 28. Moreover, depending on the preferred procurement sequence, criteria may be best applied at specific stages. Also, some activities may be let as separate contracts requiring their own criteria.

In order to identify the relevant GPP criteria, it is necessary for the public authority to contextualize the analysis of a road project, by for example targeting local conditions and materials availability. More specifically, some scenarios have a greater potential for generating large beneficial impacts from the usage of pavement related criteria (see Table 28). It is, therefore, sensible to focus pavement related efforts on those scenarios.. Conversely, if a pavement is already near the ideal scenario (little or no beneficial impact), then it may be more effective to focus efforts on other life-cycle components.

Table 28: GPP criteria application in different scenarios.

GPP criteria	Scenario where	
	Little or no potential benefits	**Large potential benefit**
Pavement-vehicle interaction Macrotexture	Low traffic flow. Low heavy traffic.	High traffic flow. High heavy traffic.
Materials	Pavements with low structural demands (*e.g.*, low AADTT, temperate climate) that require less material. High availability of recycled materials and by-products in local area.	Pavements with high structural demands (e.g., high AADTT, extreme climate) that require more material. Under development market for recycled materials and by-products in local area.
Transportation	Low overall material demand. Locally available materials, especially aggregates. Use of on-site recycling strategies. Any long-distance travel utilizes efficient transportation modes (*i.e.*, by train).	High overall material demand. Materials need to be shipped over long distances, especially aggregates. Long-distance travel using inefficient modes. Use of virgin materials for each process.
Noise – low-noise pavement and noise barriers	Roads remote from populated areas. In low traffic roads. In low speed limit roads (<50 kph).	Roads from dense populated areas and/or high speed roads. In medium-high speed roads (>50 kph) of freely flowing traffic.
Drainage -flooding	In arid or rural areas with no previous history of flooding.	In river basins with identified flood risks. In areas with high urban development.
Drainage - water pollution	In arid areas with little rainfall. In areas remote from sensitive water bodies. In low traffic flow roads.	In areas near sensitive water bodies. In high traffic flow roads.
Congestion	Pavement sections with low traffic or where capacity is much higher than demand. Sections with readily available detours. Use of lane closures during off-peak traffic periods.	Pavement sections with high traffic or where capacity is comparable to demand. Sections where detours are not readily available. Lane closures occur during peak traffic periods.

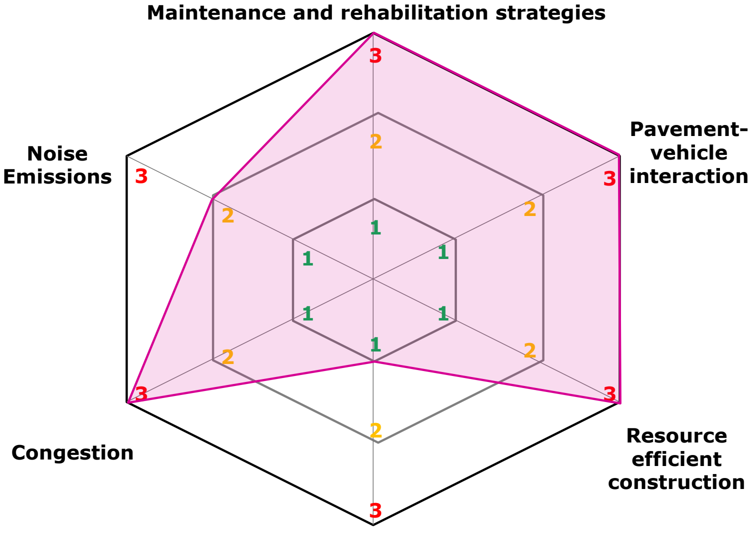
The strategic objectives and targets of the project should be determined at the outset of the project with reference to the GPP criteria set. The optimum stages for integration of GPP criteria should be evaluated during discussions to determine the procurement route. In all cases it is recommended that GPP criteria are integrated into both internal planning and the procurement sequence at the earliest possible stage in order to secure the desired outcomes and achieve the best value for money.
The relevance of different criteria in different scenarios is summarised in Table 29. Each road project is unique and the contracting authority should define at an early stage the criteria to be included in the ITT and their level of ambition.

Table 29: Relevance of GPP criteria application in different scenarios.

Scenarios	Pavement-vehicle interaction	Congestion	Resource efficient construction: Construction materials	Resource efficient construction: Soils	Resource efficient construction: Materials Transportation	Water and habitat preservation: Drainage - flooding	Water and habitat preservation: Drainage water pollution	Noise emissions: Noise – low noise pavements	Noise emissions: Noise barriers	Maintenance and rehabilitation
Low traffic flow	Green	Green	Red	Yellow	Yellow	Yellow	Green	Green	Green	Green
High traffic flow	Red	Red	Red	Yellow	Yellow	Yellow	Yellow	Red	Red	Red
Freely flowing	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Red	Yellow	Yellow
Not freely flowing	Green	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Yellow	Red
Low speed road (<50km/h)	Yellow	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
Medium-high speed road (>50km/h)	Red	Red	Yellow	Yellow	Yellow	Yellow	Yellow	Red	Red	Red
Rural road near populated area	Yellow	Red	Yellow	Yellow	Red	Red	Red	Red	Red	Red
Rural road remote from populated area	Yellow	Green	Yellow	Yellow	Yellow	Green	Green	Green	Green	Green
Urban road	Yellow	Red	Yellow	Yellow	Red	Red	Red	Red	Red	Red
Within river catchment with known flooding risk	Yellow	Yellow	Yellow	Red	Yellow	Red	Red	Yellow	Yellow	Yellow
Within arid area with no previous flooding risk	Yellow	Yellow	Yellow	Yellow	Yellow	Green	Green	Yellow	Yellow	Yellow
Road area with unsuitable subgrade soil	Yellow	Yellow	Red	Red	Yellow	Red	Yellow	Yellow	Yellow	Yellow

* green indicates that the criterion is not important for the scenario stated.
** yellow indicates that the criterion may be important but would also depend on other parameters.
*** red indicates that the criterion is important under that particular scenario.

Criteria selection web, as the ones shown in Figure 29 and Figure 30, could help identifying and communicating the relevant criteria, according to the project-specific conditions, among the different actors along the road procurement process. For example, Figure 29 refers to a high traffic rural road close to populated areas with congestion problems; in this specific scenario, it is suggested to give priority to criteria on pavement-vehicle interactions, resource efficient construction and maintenance and rehabilitation strategies. Another example is shown in Figure 30 that refers to a low traffic flow rural road close to populated areas or an urban road with flooding risk. In this specific case, it is suggested to give priority to the noise emissions and water drainage criteria.



Legend

1= the criterion is not important for the scenario analysed

2= the criterion may be important but would also depend on other parameters

3 = the criterion is important under the particular scenario analysed

Figure 29: Example of criteria selection web for a high traffic rural road close to populated areas with congestion problem.

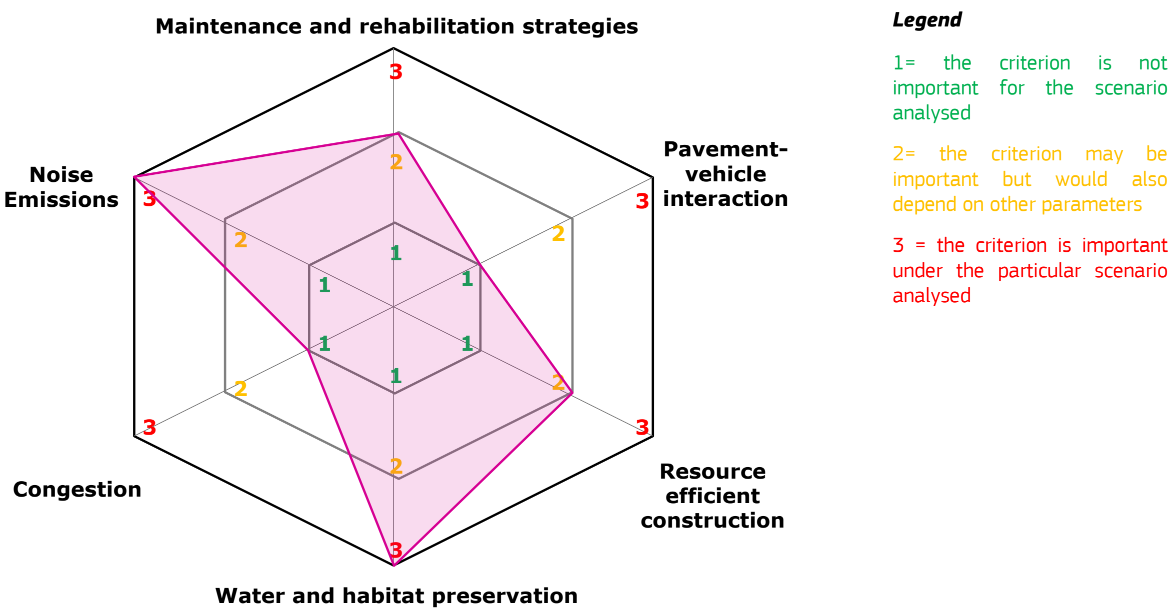


Figure 30: Example of criteria selection web for a low traffic rural road close to populated areas or in urban areas with flooding risk.

In the preceding sections the technical rationale for GPP criteria for Road design, construction and maintenance was presented. This rationale was grouped by criteria areas addressing the most significant environmental impacts associated with the design, construction and maintenance of roads. To improve the readability of the document and to facilitate cross-referencing with the GPP criteria document, a complete list of the GPP criteria with their classification and reference number in the criteria document is provided in Table 30.

In the *Procurement practice guidance document* (provided as a separate document), we describe the typical phases of procurement that may take place in the design, construction and maintenance of a roads. The criteria proposal document is structured in order to reflect the chronological order in which these activities – referred to in Table 31 as 'procurement phases' - might typically take place. This means that the order in the criteria document does not correspond to the order of the criteria areas in this technical background report. The chronological order of the criteria as they can be found in the criteria document is provided in Table 31.

Table 30: GPP criteria proposals grouped and presented by criteria areas

Title of the criterion	Procurement phase	Criterion classification	Criteria typology	Reference number in the criteria document
Competencies of the design team and contractors				
Competencies of the project manager and the design team	A. Selection of the design team and contractors	Core and Comprehensive	Selection criteria	A1
Competencies of the lead construction contractor, specialist contractors and/or property developers	A. Selection of the design team and contractors	Core and Comprehensive	Selection criteria	A2
Pavement-vehicle interaction criteria				
Rolling resistance				
Performance requirements on traffic fuel consumption due to rolling resistance	B. Detailed design and performance requirements	Comprehensive	Award criterion	B13
Quality of the completed road - monitoring of the performance parameters	C. Construction	Comprehensive	Contract performance clause	C2
Resources efficient construction				
Life cycle performance				
LCA performance of the main road elements	B. Detailed design and performance requirements	Core and Comprehensive	Award criterion	B14
Commissioning of the road construction	C. Construction	Core and Comprehensive	Contract performance clauses	C1

Commissioning of the road maintenance	E. Maintenance and operation	Core and Comprehensive	Contract performance clauses	E4
Recycled content				
Incorporation of recycled content	B. Detailed design and performance	Core and Comprehensive	Award criterion	B15
Incorporation of recycled content	C. Construction	Core and Comprehensive	Contract performance clauses	C3
Incorporation of recycled content	E. Maintenance and operation	Core and Comprehensive	Contract performance clauses	E5
Materials transportation				
Performance requirements for CO2e emissions from the	B. Detailed design and performance requirements	Core and Comprehensive	Award criterion	B16
Asphalt				
Tar-containing asphalt	E. Maintenance and operation	Core and Comprehensive	Technical specification	E1
Low temperature asphalt	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B1
Monitoring of the low temperature asphalt	C. Construction	Core and Comprehensive	Contract performance clauses	C4
Monitoring of the low temperature asphalt	E. Maintenance and operation	Core and Comprehensive	Contract performance clauses	E6
Excavated materials and soils management and waste management				
Excavated Materials and Soil Management Plan	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B2.
Commissioning of the Excavated Materials and Soil Management Plan	C. Construction	Core and Comprehensive	Contract performance clause	C5
Demolition Waste Audit and Management Plan	E. Maintenance and operation - F. End of Life	Core and Comprehensive	Technical specifications	E2 – F1.
Criteria on water and habitat preservation				
Water pollution control components in drainage system				
Performance requirements for water pollution control components in drainage systems	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B3
Requirements for water pollution control "soft engineered" components in drainage systems	B. Detailed design and performance requirements	Core and Comprehensive	Award criterion	B17
Inspection of water pollution control components in drainage systems	C. Construction	Core and Comprehensive	Contract performance clause	C6
Construction of water pollution control "soft engineered" components in drainage systems	C. Construction	Core and Comprehensive	Contract performance clause	C7
Stormwater retention capacity				
Performance requirements for stormwater retention capacity in drainage systems	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B4
Requirements for stormwater retention capacity in drainage systems that incorporate "soft engineered" components	B. Detailed design and performance requirements	Core and Comprehensive	Award criterion	B18
Inspection of stormwater retention capacity in drainage systems	C. Construction	Core and Comprehensive	Contract performance clause	C8
Inspection of stormwater retention capacity in drainage systems that incorporate "soft engineered" components	C. Construction	Core and Comprehensive	Contract performance clause	C9
Criteria for habitat creation and facilitating the passage of small fauna across the road to reduce the likelihood of wildlife fatalities.				
Environmental Integration and Restoration Plan	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B5
Performance requirements for wildlife passages across the road	B. Detailed design and performance requirements	Core and Comprehensive	Award criterion	B19
Commissioning of the Environmental Integration and Restoration Plan	C. Construction	Core and Comprehensive	Contract performance clause	C10
Inspection of wildlife passages across the road and other measures	C. Construction	Core and Comprehensive	Contract performance clause	C11

Commissioning of the Environmental Integration and Restoration Plan	E. Maintenance and operation	Core and Comprehensive	Contract performance clause	E7
Criteria on noise				
Noise emission during construction and maintenance				
Monitoring of noise emission during construction and maintenance	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B6
Monitoring noise emission during construction	C. Construction and E. Maintenance and operation	Core and Comprehensive	Contract performance clauses	C12
Monitoring of noise emission during construction and maintenance	B. Detailed design and performance requirements	Core and Comprehensive	Contract performance clauses	E8
Low-noise pavements				
Performance claim for low-noise road pavement design	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B7
Performance claim for low-noise road pavement design	B. Detailed design and performance requirements	Core and Comprehensive	Award criteria	B20
Conformity of production testing of low-noise pavement	C. Construction	Core and Comprehensive	Contract performance clause	C13
Durability of performance of low-noise pavements	D. Use	Core and comprehensive	Technical specification	D1
Durability of performance of low-noise pavements	D. Use	Core and comprehensive	Contract performance clause	D2
Other environmental criteria				
Lighting				
Performance requirement for lighting installations	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B8
Performance requirement for road markings	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B9
Criteria on congestion				
Traffic Congestion Mitigation Plan	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B10
Commissioning of the Traffic Congestion Mitigation Plan	C. Construction	Core and Comprehensive	Contract performance clauses	C14
Commissioning of the Traffic Congestion Mitigation Plan	E. Maintenance	Core and Comprehensive	Contract performance clauses	E9
Maintenance and rehabilitation strategies				
Durability				
Performance requirements for durability of pavement	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B11
Maintenance and rehabilitation strategy plan				
Maintenance and Rehabilitation (M&R) Plan	B. Detailed design and performance requirements	Core and Comprehensive	Technical specification	B12
Commissioning of the Maintenance and Rehabilitation (M&R) Plan	D. Use	Core and Comprehensive	Technical specification	D3
Commissioning of the Maintenance and Rehabilitation (M&R) Plan	E. Maintenance and operation	Core and Comprehensive	Technical specification	E3

Table 31: GPP criteria proposals grouped and presented by procurement phase.

Core criteria	Comprehensive criteria
A. Selection of the design team and contractors	
SELECTION CRITERIA	
A1. Competencies of the project manager and design team	**A1. Competencies of the project manager and design team**
A2. Competencies of the main construction contractor	**A2. Competencies of the main construction contractor**
B. Detailed design and performance requirements	
TECHNICAL SPECIFICATIONS	
B1. Low temperature asphalt	**B1. Low temperature asphalt**
B2. Excavated Materials and Soil Management Plan	**B2. Excavated Materials and Soil Management Plan**
B3. Performance requirements for water pollution control components in drainage systems	**B3. Performance requirements for water pollution control components in drainage systems**
B4. Performance requirements for stormwater retention capacity in drainage systems	**B4. Performance requirements for stormwater retention capacity in drainage systems**
B5. Environmental Integration and Restoration Plan	**B5. Environmental Integration and Restoration Plan**
B6. Monitoring of noise emission during construction and maintenance	**B6. Monitoring of noise emission during construction and maintenance**
B7. Minimum requirement for low-noise pavement design	**B7. Minimum requirement for low-noise pavement design**
B8. Performance requirement for lighting installations	**B8. Performance requirement for lighting installations**
B9. Performance requirement for road markings	**B9. Performance requirement for road markings**
B10. Traffic Congestion Mitigation Plan	**B10. Traffic Congestion Mitigation Plan**
B11. Performance requirements for durability of pavement	**B11. Performance requirements for durability of pavement**
B12. Maintenance and Rehabilitation (M&R) Plan	**B12. Maintenance and Rehabilitation (M&R) Plan**
AWARD CRITERIA	
B13. N/A	**B13. Performance requirements on traffic fuel consumption due to rolling resistance**
B14. LCA performance of the main road elements	**B14. LCA performance of the main road elements**
B15. Incorporation of recycled content	**B15. Incorporation of recycled content**
B16. Performance requirements for CO_2e emissions from the transportation of aggregates	**B16. Performance requirements for CO_2e emissions from the transportation of aggregates**
B17. Requirements for water pollution control "soft engineered" components in drainage systems	**B17. Requirements for water pollution control "soft engineered" components in drainage systems**

B18. Requirements for stormwater retention capacity in drainage systems that incorporate "soft engineered" components	**B18. Requirements for stormwater retention capacity in drainage systems that incorporate "soft engineered" components**
B19. Performance requirements for wildlife passages across the road	**B19. Performance requirements for wildlife passages across the road**
B20. Performance claim for low-noise road pavement design	**B20. Performance claim for low-noise road pavement design**
C. Construction or major extensions	
CONTRACT PERFORMANCE CLAUSE	
C1. Commissioning of the road construction	**C1. Commissioning of the road construction**
C2. N/A	**C2. Quality of the completed road – monitoring of the performance parameters**
C3. Incorporation of recycled content	**C3. Incorporation of recycled content**
C4. Monitoring of the low temperature asphalt	**C4. Monitoring of the low temperature asphalt**
C5. Commissioning of the Excavated Materials and Soil Management Plan	**C5. Commissioning of the Excavated Materials and Soil Management Plan**
C6. Inspection of water pollution control components in drainage systems	**C6. Inspection of water pollution control components in drainage systems**
C7. Construction of water pollution control "soft engineered" components in drainage systems	**C7. Construction of water pollution control "soft engineered" components in drainage systems**
C8. Inspection of stormwater retention capacity in drainage systems	**C8. Inspection of stormwater retention capacity in drainage systems**
C9. Inspection of stormwater retention capacity in drainage systems that incorporate "soft engineered" components	**C9. Inspection of stormwater retention capacity in drainage systems that incorporate "soft engineered" components**
C10. Commissioning of the Environmental Integration and Restoration Plan	**C10. Commissioning of the Environmental Integration and Restoration Plan**
C11. Inspection of wildlife passages across the road and other measures	**C11. Inspection of wildlife passages across the road and other measures**
C12. Monitoring noise emission during construction	**C12. Monitoring noise emission during construction**
C13. Conformity of production testing of low-noise pavements	**C13. Conformity of production testing of low-noise pavements**
C14. Commissioning of the Traffic Congestion Mitigation Plan	**C14. Commissioning of the Traffic Congestion Mitigation Plan**
D. Use of the road	
TECHNICAL SPECIFICATIONS	
D1. Durability of performance of low-noise pavements	**D1. Durability of performance of low-noise pavements**
CONTRACT PERFORMANCE CLAUSE	
D2. Durability of performance of low-noise pavements	**D2. Durability of performance of low-noise pavements**
D3. Commissioning of the Maintenance and Rehabilitation (M&R) Plan	**D3. Commissioning of the Maintenance and Rehabilitation (M&R) Plan**

E. Maintenance and operation	
TECHNICAL SPECIFICATIONS	
E1. Tar-containing asphalt	**E1. Tar-containing asphalt**
E2. Demolition Waste Audit and Management Plan	**E2. Demolition Waste Audit and Management Plan**
CONTRACT PERFORMANCE CLAUSES	
E3. Commissioning of the Maintenance and Rehabilitation (M&R) Plan	**E3. Commissioning of the Maintenance and Rehabilitation (M&R) Plan**
E4. Commissioning of the road maintenance	**E4. Commissioning of the road maintenance**
E5. Incorporation of recycled content	**E5. Incorporation of recycled content**
E6. Monitoring of the low temperature asphalt	**E6. Monitoring of the low temperature asphalt**
E7. Commissioning of the Environmental Integration and Restoration Plan	**E7. Commissioning of the Environmental Integration and Restoration Plan**
E8. Monitoring noise emission during maintenance	**E8. Monitoring noise emission during maintenance**
E9. Commissioning of the Traffic Congestion Mitigation Plan	**E9. Commissioning of the Traffic Congestion Mitigation Plan**
F. End of life	
TECHNICAL SPECIFICATIONS	
F1. Demolition waste audit and management plan	**F1. Demolition waste audit and management plan**
PROPOSED TECHNICAL ANNEXES	
Annex A. Supporting guidance for criterion B14 (core criterion): Option 1 – Carbon footprint (CF)	
Annex B. Supporting guidance for criterion B14 (comprehensive criterion): Option 2 – Life Cycle Assessment analysis (LCA)	
Annex C. Brief for LCA technical evaluator	

3 Life Cycle Costing

3.1 Introduction to Life Cycle Cost

Whole Life Cost (WLC) is defined by the ISO 15686-5 standard and it is composed by a) non-construction costs, b) Life Cycle Cost (LCC), including construction, maintenance and operation, end of life, c) income and d) externalities.

LCC analysis is an evaluation technique within the asset management framework that is used to support investment decisions. LCC analysis is applied when a road authority is planning a new investment or a maintenance and rehabilitation strategy and seeks to determine the lowest life cycle cost project (*i.e.*, the most cost-effective project). LCC analysis does not usually include externalities. NRAs in Europe have to find a balance between growing transportation demand, ageing infrastructures, and diminishing resources. Asset management (AM) provides a systematic process for maintaining, upgrading, and operating physical assets in a cost-effective manner using a series of road management procedures and tools for both short- and long-term planning. The goal of AM is to get the best results and performance from the preservation, improvement, and operation of infrastructure assets with the resources available. The LCC should be performed early in the design process.

3.2 The cost of infrastructures in Europe

3.2.1 European road network and maintenance investments

According to data collected by the International Transport Forum at the OECD (ITF, 2012), total spending on road network investment and maintenance amounted to about 1% of GDP in the OECD on average in the last 15 years. The balance between road maintenance and investment has remained relatively constant over time in many regions, with maintenance making up 30% of total road expenditure on average. The volume of maintenance for road infrastructure in Western European countries has increased slightly more rapidly than the volume of investment: the former grew by 25%, while the latter by around 21% from 1995 to 2008. This resulted in an increased share of maintenance in total road expenditure, from 26% in 1997 to 30% in 2009.

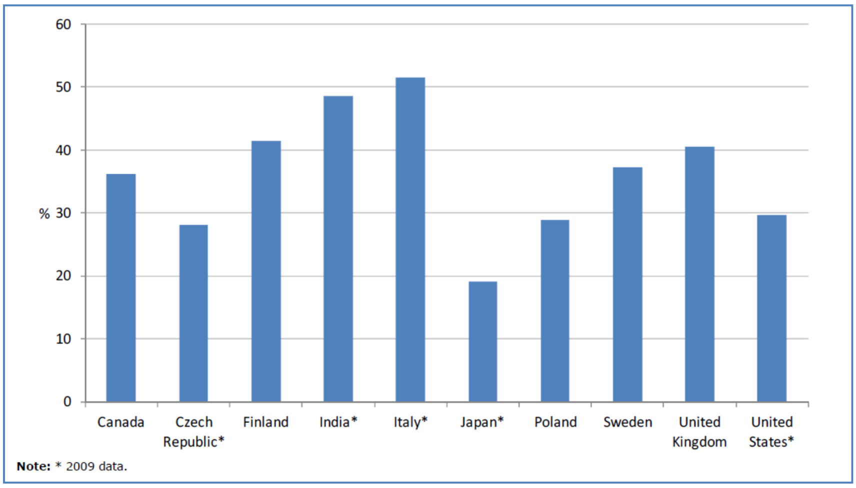


Figure 31: Road maintenance share of the total expenditure 2010 (at current prices) (ITF, 2012).

3.2.2 Total cost of infrastructure in Europe

With reference to Braconier *et al.* (2013) and CEDR (2013), road costs can be divided into three components:

- Infrastructure and maintenance costs (including land acquisition, construction, preventive/routine maintenance and rehabilitation). These costs are borne by the road authority.

- User costs (associated with work areas: delays due to congestion, accidents, vehicle operating costs, *etc.*).

- Costs of negative externalities, included when a WLC is performed.

An estimation of the total cost of infrastructure has been included within the European transport research and policy development, as the IMPACT study (Doll and van Hessen, 2008). In the deliverable IMPACT D2 (2008), the current cost structures and revenues of European road infrastructures are summarised. The report is aimed at building up a quantitative database on total road infrastructure costs for EU-28 MSs and does not include environmental and safety aspects. Total costs have been derived by analysing the results of recent studies, as the EU research project UNITE (2003) on country accounts and national studies for Germany (ProgTrans/IWW, 2007; Prognos/IWW, 2002 on behalf of BMVBS), Switzerland (Bundesamt fuer Statistik, 2007), Austria ((Herry *et al.*, 2002 on behalf of ASFINAG) and the Netherlands (CE, 2004). The results have been extrapolated for EU-28. The cost structures include discussions of total costs and their variability with region and traffic characteristics, average costs by vehicle type as well as the marginal social infrastructure costs (see Annex 7, Table A2). Road networks have been classified into three basic types of infrastructure: motorways, other trunk roads and local and urban roads.

According to IMPACT D2, a common structure of cost categories is:

- *Investment expenditures*: planning and surveying, land purchase, earthworks and ground works, sub-grade and sub-base, binder and surface courses), engineering works, equipment as traffic signs, *etc.*;

- *Running costs*: repair measures, operation (winter maintenance, green cutting, *etc.*), traffic police, administration and toll collection.

The resulting unit costs per road category and road kilometre for those countries with road class specific accounts are depicted in Figure 32. It is significant that motorway construction costs are roughly ten times higher than the costs of trunk or urban roads. According to IMPACT D2 (2008), the analysis of the country accounts of the unit costs per road kilometre reveals similarities of cost levels and cost structures between the big Western European countries. For these countries we found values between € 600,000 (Austria, Germany, Italy, Spain) and € 800,000 (France) per motorway kilometre. Less reliable are the results presented for other road types and for the new Member States. The main findings of the country comparison of unit costs per road kilometre were that the unit costs for motorways are roughly ten times higher than those for trunk or urban roads. Regional results for Austria and Switzerland reveal that the running costs are 20 to 50% higher in mountainous areas than in relatively flat regions. Results for capital costs are not available, but it can be foresee that the need for more bridge and tunnel constructions pushes up construction costs in mountainous areas considerably.

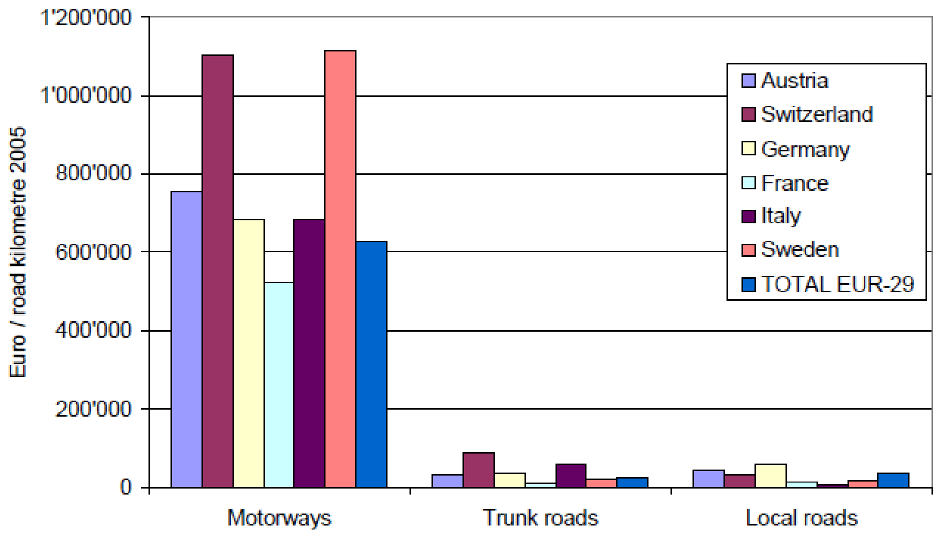


Figure 32: Unit road infrastructure costs for EU-28 and Switzerland and three types of road.

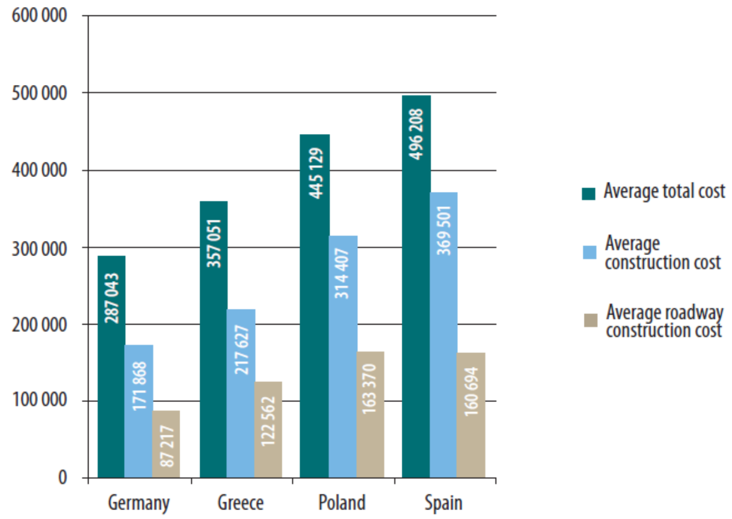
As it has been indicated in the **B**enchmark of **Ex**penditures and **Prac**tices of maintenance and operation (BEXPRAC) study launched by CEDR in 2008, the criteria used by the NRAs to define the items that represent the different components of the road network and the way of defining LCC are not homogeneous in Europe. Some NRAs, such as in the Netherlands, Switzerland, United Kingdom have already implemented a comprehensive AM/LCC system, other NRAs, such as in France, Italy, Slovenia, Spain, have started to develop such an approach. LCC often is the first step towards creating a comprehensive asset management (AM) approach. There are many differences in terms of ownership and management and other differences regarding the capitalisation of expenditures by NRAs (CEDR, 2013).

According to Ricardo AEA (2014), marginal road infrastructure costs correspond to the increase in road maintenance and repair expenditures that are induced by higher traffic levels. These effects can differ by country, road type and vehicle class. Heavier vehicles tend to cause more damage to the roads, thus the focus of infrastructure cost studies is usually on HGVs. Variable costs include certain elements of the investment expenditure and running costs reported in the road accounts, namely (definitions adapted from BFS (2011):

- *Routine maintenance* and large repair measures (part of capital costs): periodical measures to ensure the required conditions, including major repairs and activities to strengthen the engineering structure.
- *Operational maintenance* (part of running costs): includes measures to ensure the continuous operability of the road, such as cleaning, inspection, surface treatment, winter maintenance, lighting and minor repairs to maintain the functionality.

With reference to the Sansom *et al.*, (2002), the marginal cost include: long-life pavements, resurfacing, overlay, surface dressing, patching and minor repairs, drainage and road markings. Marginal cost is estimated as around 40-50% of average cost, with marginal cost varying between vehicle types mainly on the basis of standard axle kilometres. According to Lindberg, 2006 and other publications, there is a close link between the marginal infrastructure costs (constructing, maintaining, repairing, operating, servicing and administrating the infrastructure) and the user costs (cost for traffic congestion, scarcity and degrading quality). Increasing user costs indicate the need for infrastructure investments or operational activities Construction and maintenance activities may cause congestion and omitted maintenance may cause safety problems.

The projects audited by the European Court of Auditors (2013) shows that projects audited in Germany had the lowest cost per 1 000 m^2 in all three categories. For the projects audited in Spain, there is considerable difference between the total construction and roadway construction costs. This indicates a heavy use of engineering objects such as bridges or tunnels (see Figure 33).



[1] For comparison of Polish projects long-term average exchange rate of 4 zloty = 1 euro was used for all calculations.
Source: Calculation by the Court of Auditors.

Figure 33: Average total cost, total construction cost and roadway construction cost for 1,000 m^2 of the road projects audited per MS in Euro (European Court of Auditors, 2013).

3.2.3 Externalities

Transport activities give rise to environmental impacts, accidents, congestion, and infrastructure wear and tear. The internalisation of external costs means making such effects part of the decision-making process of transport users. The Handbook on external costs estimation (Maibach *et al.*, 2008[39]) that was produced in 2008 as an output of the IMPACT study presented the state of the art and best practice on the methodology for different cost categories. An updated handbook, published by Ricardo AEA (2014), continues to present the state of the art and best practice on external cost estimation. Accordingly, the most recent information for the following impact categories has been gathered:

1. Congestion;
2. Accidents;
3. Noise;
4. Air pollution;
5. Climate change;
6. Other environmental impacts (costs of up- and downstream processes);
7. Infrastructure wear and tear for road.

There is a general consensus on the major methodological issues. The best practice estimation of congestion costs is based on speed-flow relations, value of time and demand elasticity. For air pollution and noise costs, the impact pathway (or damage cost) approach is broadly acknowledged as the preferred methodology. The valuation of the respective health effects is based on the willingness-to-pay concept. Marginal accident cost can be estimated by the risk elasticity approach, using values of statistical life. Given long-term reduction targets for GHG emissions, the abatement cost approach. The external costs of transport activities depend strongly on parameters like location (urban, interurban), time of day (peak, off-peak, night-time) as well as on vehicle characteristics (*e.g.*, EURO standards for pollutant emissions).

3.3 Life Cycle Cost Analysis

3.3.1 Introduction

According to FHWA (2002), LCC analysis will assist in determining the best (the lowest-cost) way to accomplish the project. LCC analysis is a subset of benefit-cost analysis (BCA); the latter compares benefits among different alternatives, including externalities. The LCC analysis enables the total cost comparison of competing design (or preservation) alternatives that would yield the same level of service, by means of the following steps:

- Establish design alternatives. The construction or major rehabilitation of an asset is only the first of these activities; periodic maintenance and subsequent rehabilitation are required for the design alternatives under study to provide a specified level of performance throughout its life. *For example, Alternative A is characterized by fewer construction and rehabilitation activities than is Alternative B, but the activities it requires are more extensive and cost more, per activity, than those of Alternative B.*

- Determine activity timing. Each alternative's M&R Plan is developed.

- Estimate costs: road authority costs (initial construction and periodic M&R activities) and user (including vehicle operating costs, congestion and accident costs), using a discount factor.

- Compute life-cycle costs and analyse the results. *For example, Alternative A has the lowest combined road authority and user costs, whereas Alternative B has the lowest initial construction and total road authority costs. Based on this information alone, the decision-maker could lean toward either Alternative A (based on overall cost) or Alternative B (due to its lower initial and total road authority costs). Sensitivity analysis could be performed based on discount rates or key assumptions concerning construction and rehabilitation costs. Finally, a probabilistic analysis could help capturing the effects of uncertainty in estimates of timing or magnitude of costs.*

An example of a LCC analysis performed in the Pothole project (Hartmann 2013) is shown in Figure 34.

39 http://ec.europa.eu/transport/themes/sustainable/internalisation_en.htm

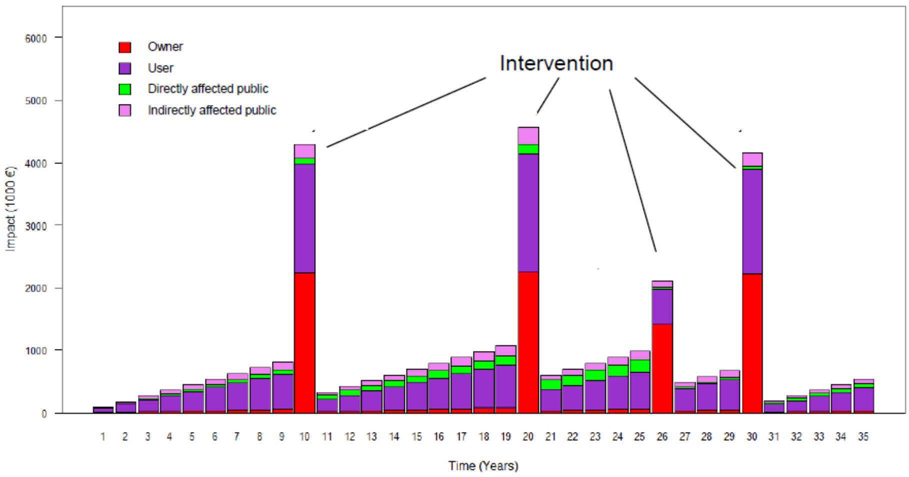


Figure 34: Possible cost flow over the life-cycle of road assets (Hartmann, 2013).

3.3.2 LCC to support the development of GPP criteria for Road Design, Construction and Maintenance

Every road project is unique and this is reflected also in the LCC. Therefore, it is challenging trying to collect cost data. Drawing general conclusion is not possible. However, a cost collection exercise has been carried out in order to support the criteria development process.

Several examples of road construction and maintenance costs data have been collected from different LCC analyses for the following scenarios:

1. Motorway and/or highway (with 2 lanes per carriageway);
2. Secondary or regional road;
3. Local road (urban and rural).

Service life is on average around 30-35 years in the evaluated LCC analyses.

First, the results of a summary paper on cost of road construction and maintenance of highways and motorways will be reported (OECD, 2005), then additional cost data will be included.

3.3.2.1 Collection of cost data for road construction and maintenance of highways and motorways

With reference to OECD (2005), the typical pavement structures used for paving projects on high traffic roads (highways and motorways) are reported as follows (see Annex 7, Table A. 3):

a) surface course generally with a thickness of 30-40 mm;
b) binder course (HMA) with a thickness of 200 mm to 240 mm;
c) base, road-base and sub-base courses with a total thickness from 300 mm to 1,200 mm.

The pavement design life is typically 20 years or longer.

Information on traffic, design methods, expected life of the surface course, failure criteria used by agencies with respect to smoothness, rutting, distress and skid resistance are provided in Annex 7, Table A. 4. IRI is used extensively by most agencies as a measure of pavement performance and also as a measure of construction quality for projects. The reported failure criteria for IRI vary from 2.2 to 4.4, with 2.4 as a common response. The rut depth criteria to initiate maintenance were reported to be from 13 to 25 mm with 15 mm as a common response. Skid resistance is a common failure criteria used by agencies and a minimum skid value was noted from 0.35 to 0.4. Noise measurements were not routinely. Noise reduction is a very important consideration for the Netherlands (OECD, 2005).

Initial costs and maintenance strategies Table 32 shows the initial costs of surface course materials, the typical thicknesses, the expected life, maintenance strategies and closure durations are shown in Table 32. Initial costs include only the costs of the materials, the mixing, haul, placement and traffic control for the work. These costs are the all-inclusive contractor's bid costs for work and do not include such items as design costs, road authority project supervision costs or other ancillary project costs (OECD, 2005).

With reference to closure duration for maintenance activities, typical road closure durations for crack sealing operations range from 0.2 to 1.0 days per lane kilometre, and typical road closure durations for patching were from 0.33 to 1.0 days. Road closure durations for surface seal or chip seal ranged from 0.2 to 2.0 days.

Table 32: Initial costs and maintenance strategies for surface courses (OECD 2005).

Country	**Initial costs** (€/m²)	**Thickness** (mm)	**Expected life of surface** (y)	**Maintenance strategy**	**Frequency**	**Costs** (€/km·lane)	**Closure** (days)	**Notes**
Canada	5.5	50	15	Crack seal	2-9-15	1,000	0.2	Superpave
				Surface seat/hot in place	12	20,000	2	
				Mill and replace	15	30,000	1	
	5.5	50	15	Crack seal	2	1,000	0.2	class 1 mix
				Patch	10	10,000	1	
				Surface seat/hot in place	12	20,000	2	
				Mill and replace	15	30,000	4	
	3	40	15	Crack seal	3-9-15	1,000	1	Dense friction course
				Patch	9, 15	8,000	1	
				Mill and replace	19	73,000	1	
Denmark	5.3	20	14	Crack seal	8	1,000	0.33	TB(thin-layer)
				Patch	10, 13	3,000	0.33	
				Overlay	14	20,000	1	
	9.5	35	14	Crack seal	8	1,000	0.33	SMA
				Patch	10,13	3,000	0.33	
				Mill and replace	14	35,000	1	
Finland	5	40	5	Mill and replace	5	20,000	0.5	
France	3	25	16	Crack seal	5		1	
				Mill and replace	16			
Hungary	8	40	7	Patch	3	100	0.5	SMA
				Patch	5	200	0.5	
				Overlay	7	100,000	1	
Netherlands	10.6	50	15	Mill and replace	9	65,000	0.8	Porous asphalt, new construction
	15.6	50	15	Mill and replace	15	86,000	0.8	Porous asphalt, rehabilitation
Norway	6.7	35	5	Mill and replace	5	24,300	1	SMA
Poland	6.94	40	10	Thin overlay	10	20,000	0.5	SMA
				Mill and replace	20	26,000	0.75	
	9.2	50	10	Thin overlay	10	24,000	0.4	Asphalt concrete
				Mill and replace	20	32,000	1	
Portugal	3.44	40	15	Crack seal	3,6,12	2,600	2	SMA
				Mill and replace	15	16,000	1	
Sweden	3	20	9	Mill and replace	9	15,000	1	TSK thin layer
				Seal Coat(SDI)	9	4,000	0.2	SMA
				Mill and replace	13	30,000	2	
UK	6.61	25	9	Crack seal, Mill and replace	8,9			SMA
	8.61	30	9	Crack seal	8	2,000	0.5	
				Mill and replace	9	34,000	0.4	
	9.5	30	9	Mill and replace	9,27	20,000	0.5	
				Mill and replace	18,35	33,000	1	
USA	4.9	50	18	Crack seal	3			HMA
				Surface seal	8	3,500	0.04	Minnesota
				Overlay	18	20,000	1	
	5.6	50	10	Crack seal	5,10	2,000	1	SMA
				Mill and replace	10	27,000	2	Colorado
	35	320	30	Crack seal	20	320,000	10	Concrete
				Grinding	20	240,000	10	Florida

3.3.2.2 Collection of additional cost data for road construction and maintenance

Additional road construction and maintenance costs have been updated in order to find additional and compare results for the same scenarios reported in section 3.3.2. Data have been collected from different sources in different countries. Nordic countries such as Canada or Denmark or central Europe as Belgium are more covered than other MSs. A huge variability among cost data can be observed according to the uniqueness of every project. Therefore, it is not possible to compare costs data coming from different projects and to draw general conclusions. Costs are reported in order to have an order of magnitude and to highlighting the main cost chapters in road construction and maintenance activities.

3.3.2.2.1 Cost of road construction

Cost of earth works, ground works, soil preparation and stabilization

In Table 33 some examples of costs for earth works, ground works, soil preparation and stabilization (including sub-grade preparation) are provided.

Table 33: Cost of earth works, ground works, soil preparation and stabilization (including sub-grade preparation).

Cost adapted from [€/km·lane]	**Pavement**	**Motorway and/or highway**	**Secondary or regional road**	**Local road**
ARA (2011)[a)]	Flexible	High: 43,000 Medium: 36,000-41,000 Low: 33,000	High: 32,000 Medium: 28,000-29,000 Low: 27,000	n.a.
	Rigid	High: 21,000 Medium: 18,000-19,000 Low: 18,000	High: 18,000 Medium: 17,000-18,000 Low: 17,000	n.a.
VD (2014)[b)]		89,000-141,000	n.a.	n.a.
COWI (2014)[b)]		N/A	14,000	13,000

Motorway/highway (2 lane per carriageway):
High: AADTT 10000
Medium: AADTT 5000-7000
Low: AADTT 2500
a) Converted from CAD – 1.4781 exchange rate (July 2014)
b) Converted from DKK - 7.4557 exchange rate (July 2014)

Secondary/regional roads (1 lane per carriageway):
High: AADTT 1500
Medium: AADTT 500-1000
Low: AADTT 250

A lane width of 3.5-3.75 meters

Cost of sub-base and road-base

In Table 34 some examples of cost of sub-base and road-base for construction of flexible pavements are provided. Data have been adapted from different sources.

With reference to unbound materials, such as aggregates and by-products to be used in road-base and sub-base the average price for natural aggregates at the extraction site in 2007 varied from 2.5 to 12 €/t; being that in most MSs prices vary from 6 to 7 €/t (Böhmer et al., 2008; EC JRC, 2009; WBCSD , 2009). According to Garbarino and Blengini (2013) and BIOIS (2011), recycled concrete aggregates can sell in EU for 3 to 12 €/t, with a production cost of 2.5 to 10 €/t. Up to 50 % of the price of aggregates could be ascribed to transportation costs (WRAP, 2005; Parikka-Alhola and Nissinen, 2008). With reference to manufactured aggregates used in road construction, prices of 20€/t for ground granulated BSF and 10 €/t for fly ash have been found in commercial websites.

Table 34: Cost of sub-base and road-base for flexible pavements.

Cost adapted from [€/km·lane]	**Pavement**	**Motorway and/or highway**	**Secondary or regional road**	**Local road**
ARA (2011)[a)]	Flexible	High: 45,000 Medium: 37,000-42,000 Low: 32,000	High: 31,000 Medium: 27,000-28,000 Low: 24,000	n.a.
VD (2014)[b)]	Flexible	54,000 (sub-base) 57,000 (road-base)	n.a.	n.a.
COWI (2014)[b)]	Flexible	n.a.	64,000	49,000
Federbeton (2010)	Flexible	32,000	n.a.	n.a.

Motorway/highway (2 lane per carriageway):
High: AADTT 10000 Medium: AADTT 5000-7000 Low: AADTT 2500
a) Converted from CAD – 1.4781 exchange rate (July 2014)
b) Converted from DKK - 7.4557 exchange rate (July 2014)

Secondary/regional roads (1 lane per carriageway):
High: AADTT 1500 Medium: AADTT 500-1000 Low: AADTT 250
A lane width of 3.5-3.75 meters

Costs of surface, binder and base courses

Some examples of cost for different asphalt mixes (HMA, WMA and CMA) for surface, binder and base courses and for three identified scenarios (motorway/highway, secondary/regional, local roads) are provided in Table 35. Not every combination is included, as for example CMA is not recommended for highways and motorways.

Table 35: Cost of flexible pavements disaggregated by course for different asphalt mixes.

Cost adapted from [€/km·lane]	**Course**	**Thickness (mm)**	**HMA**	**WMA***	**CMA***
ARA (2011)[a]	Surface	40 40	Motorway/highway High: 33,000 Medium: 29,000-31,000 Low: 29,000 Secondary/regional High: 30,000 Medium: 26,000-29,000 Low: 26,000	Motorway/highway High:30,000-33,000 Medium: 26,000-31,000 Low: 26,000-30,000 Secondary/regional High: 26,000-30,000 Medium: 23,000-29,000 Low: 23,000-26,000	Motorway/highway CMA not used Secondary/regional High: 29,500 Medium:26,000-29,000 Low: 26,000
	Binder	100-140 80-100	Motorway/highway High: 90,000 Medium: 70,000-83,000 Low: 64,000 Secondary/regional High: 60,000 Medium: 48,000-50,000 Low: 48,000	Motorway/highway High: 81,000-90,000 Medium: 63,000-83,000 Low: 58,000-64,000 Secondary/regional High: 54,000-60,000 Medium: 43,000-49,000 Low: 43,000- 48,000	Motorway/highway CMA not used Secondary/regional CMA not used
	Base	150-200 80-100	Motorway/highway High: 18,000 Medium: 16,000-18,000 Low: 16,000 Secondary/regional High: 17,000 Medium: 16,000 Low: 16,000	Motorway/highway High: 16,000-18,000 Medium: 15,000-18,000 Low: 15,000-17,000 Secondary/regional High: 15,000-17,000 Medium: 15,000-17,000 Low: 15,000-17,000	Motorway/highway CMA not used Secondary/regional CMA not used
COWI (2014)[b]	Surface	35 35 25	Motorway/highway 67,000 Secondary/regional 67,000 Local road 55,000	Motorway/highway 60,000-67,000 Secondary/regional 60,000-67,000 Local 50,000-55,000	Motorway/highway CMA not used Secondary/regional 67,000 Local 55,000
	Binder	56 56	Motorway/highway 70,000 Secondary/regional 70,000 Local road (0mm) No binder	Motorway/highway 63,000-70,000 Secondary/regional 63,000-70,000 Local road (0mm) No binder	Motorway/highway CMA not used Secondary/regional CMA not used Local road (0mm) No binder
	Base	144 60 70	Motorway/highway 140,000 Secondary/regional 60,000 Local 82,000	Motorway/highway 126,000-140,000 Secondary/regional 54,000-60,000 Local road 74,000-82,000	Motorway/highway CMA not used Secondary/regional 60,000 Local road 82,000
Federbeton (2010)	Surface	200	Motorway/highway 18,000	n.a.	n.a.
	Binder	260	Motorway/highway 47,000-59,000	n.a.	n.a.
	Base	300	Motorway/highway 16,000-18,000	n.a.	n.a.

Motorway/highway (2 lane per carriageway):
High: AADTT 10000 Medium: AADTT 5000-7000 Low: AADTT 2500
[a] Converted from CAD – 1.4781 exchange rate (July 2014)
[b] Converted from DKK - 7.4557 exchange rate (July 2014)
*calculated based on information received on HMA and CMA from Norway and Sweden (COWI, 2014)

Secondary/regional roads (1 lane per carriageway):
High: AADTT 1500 Medium: AADTT 500-1000 Low: AADTT 250
A lane width of 3.5-3.75 meters

Energy savings on WMA is 15-20% compared to HMA; with reference to any economic benefits from using WMA, in general the costs are considered to be the same or lower than HMA (COWI, 2014). According to STA (SE) Trafikverket (SE), the energy saving of using CMA is approximately 60% compared to HMA, nevertheless, the economic costs are still the same (COWI, 2014).

Cost of RAP

According to COWI (2014), based on limited Danish experience from national tenders of asphalt pavement works (based on V&S, 2011), asphalt with 30% RAP is 4% cheaper in off-site hot mixing plant and 29% cheaper in on-site hot mixing plant than asphalt produced with 100% of natural aggregates, in both mixing plants. It has to be considered that on-site and off-site productions use different technologies. A simplified relationship between % of RAP in WMA and material cost (Burke *et al.*, 2007) is reported in Figure 35. According to EAPA (2008), the costs of using RAP have to be considered in a full LCC as disposal fees have large impact on whether using RAP is economically advantageous. Within the EU member states the prices also largely depend on fees and the strategies used. For example, In UK a landfill tax is used to stimulate recycling, whereas in Sweden a bonus is given if the RAP content is above, *e.g.*, 10% and a deduction if the RAP content is below. In the Netherlands there is, however, a complete ban of disposing of materials that may be recycled. Therefore, it is very difficult to provide values applicable for all EU MSs (COWI, 2014).

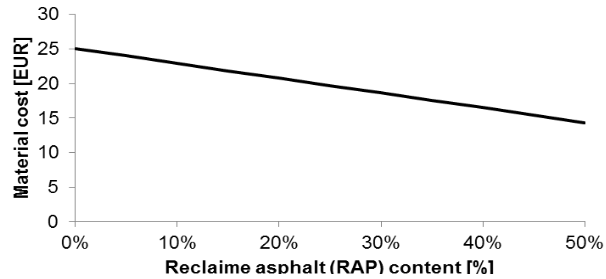


Figure 35: Material costs related to RAP content in warm-mix asphalt (Burke *et al.*, 2007). Value are based on costs in Iceland and the USA Material costs don't include RAP milling costs (COWI, 2014).

Costs of low-noise pavements

COWI (2014) reported that for low-noise pavement in Denmark a thin-layer asphalt course are used, at both regional and local roads, with a cost of 25,800 euro/km·lane according to recent tenders (2014). In The Netherlands, a porous asphalt pavement costs approximately 37,300 euro/km·lane (2014).

Cost for rigid and semi-rigid pavements

Some examples of costs for rigid and semi-rigid pavements are provided in Table 36. According to COWI (2014), semi-rigid pavements are approximately 10% cheaper than a rigid pavement in a case study presented in V&S, 2011.

Table 36: Cost for rigid and semi-rigid pavements.

Cost adapted from [€/km·lane]	**Pavement**	**Course**	**Thickness (mm)**	**Scenarios**
ARA (2011)[a]	Rigid	Surface	40	Motorway/highway High: 140,000 Medium: 126,000-135,000 Low: 126,000
			40	Secondary/regional roads High: 126,000 Medium: 108,000-126,000 Low: 105,000
		Slab	150-200	Motorway/highway High: 24,000 Medium: 22,000-24,000 Low: 22,000
			80-100	Secondary/regional roads High: 22,000 Medium: 22,000 Low: 22,000
COWI (2014)[b]	Rigid	Concrete pavement		Motorway/highway: 265,000 Secondary/regional roads: 240,000
Federbeton (2010)	Semi-rigid	pavement	760	Motorway/highway: 158,000-225,000

Motorway/highway (2 lane per carriageway):
High: AADTT 10000 Medium: AADTT 5000-7000 Low: AADTT 2500
[a] Converted from CAD – 1.4781 exchange rate (July 2014)

Secondary/regional roads (1 lane per carriageway):
High: AADTT 1500 Medium: AADTT 500-1000 Low: AADTT 250
A lane width of 3.5-3.75 meters

3.3.2.2.2 Cost of maintenance

Cost of routine maintenance

Some examples of costs and expected frequency of routine maintenance for flexible pavements have been collected at least for crack-sealing, pothole repair, minor correction of surface texture deficiencies, minor shape correction (see Table 37). According to COWI (2014), the Danish Road Directorate reported a crack sealing (immediately after detection) cost of 750 €/m² for motorways and other primary roads. In Table 38, the costs for pothole repairs from the Pothole EU project (Hartmann, 2013) are reported. Some examples of costs and expected frequency of routine maintenance for rigid and semi-rigid pavements are reported in Table 39.

Table 37: Costs and expected frequencies of routine maintenance on flexible pavements.

Cost adapted from	Scenario	Truck Traffic AADTT	Maintenance	per 1 of km road	First maintenance activity after construction (year)	Frequency (years)	Cost [€/km·lane]
ARA (2011)[a]	Motorway highway	High	Crack sealing Pothole repair	100-500 m 5-10%	8 8	5-8 5-8	1300 14000
		Medium	Crack sealing Pothole repair	100-500 m 5-10%	5 10	5-10 10	800-1,200 5,800-14,000
		Low	Crack sealing Pothole repair	100-500 m 5-10%	5 10	5 10	800 5800
	Secondary /regional roads	High	Crack sealing Pothole repair	100-500 m 5-10%	10 10	5-10 8-10	630 4300
		Medium	Crack sealing Pothole repair	250-500 m 2-10%	10 10	5-10 5-10	630 2,700
		Low	Crack seal Pothole repair	250-500 m 2-5%	10 10	5-10 10	630 2,700
COWI (2014)[b]	Local roads		Crack sealing Pothole repair	5% of surface per year [c]		After 3-5	670-8,000 200-4,200
Federbeton (2010)	Motorway /highway		Crack sealing Pothole repair		4 4	7 1(after 4)	2,600 20,000

Motorway/highway (2 lane per carriageway):
High: AADTT 10000 Medium: AADTT 5000-7000 Low: AADTT 2500
[a] Converted from CAD – 1.4781 exchange rate (July 2014)
[b] Converted from DKK - 7.4557 exchange rate (July 2014)

Secondary/regional roads (1 lane per carriageway):
High: AADTT 1500 Medium: AADTT 500-1000 Low: AADTT 250
A lane width of 3.5-3.75 meters
[c] based on Gavrilescu

Table 38: Costs of pothole repairs (Hartmann, 2013).

Type	Repair material	Repair technique	Repair costs (€/m²)	Traffic management costs(€/m²)	Patching survival (years)
1a	CMA	Unprepared fill-and-roll	50	400	0.4
1b	CMA	prepared fill-and-roll	60	400	2
2a	Synthetic binder	prepared fill-and-roll	70	400	3
3a	HMA	Unprepared fill-and-roll	60	400	2
3b	HMA	prepared fill-and-compaction	70	400	4

Table 39: Costs and expected frequencies of routine maintenance on rigid and semi-rigid pavements.

Cost adapted from	Pavement	Scenario	Truck Traffic AADTT	Maintenance	per 1 km of road	First maintenance activity after construction (year)	Frequency (years)	Cost [€/km·lane]
ARA (2011)[a]	Rigid	Motorway /highway	High	Joint sealing	50%	12	12-15	2,150
			Medium	Joint sealing	25%	12	12-15	1,400-2,150
			Low	Joint sealing	25%	12	12-15	1,400
	Rigid	Secondary /regional	High	Joint sealing	20-25%	12	12-15	1,250
			Medium	Joint sealing	10-20%	12	12-15	900-1,250
			Low	Joint sealing	10-20%	12	12-15	900

Motorway/highway (2 lane per carriageway):
High: AADTT 10000 Medium: AADTT 5000-7000 Low: AADTT 2500
[a] Converted from CAD – 1.4781 exchange rate (July 2014)

Secondary/regional roads (1 lane per carriageway):
High: AADTT 1500 Medium: AADTT 500-1000 Low: AADTT 250
A lane width of 3.5-3.75 meters

Cost of preventive maintenance and rehabilitation

Some examples of cost and expected frequency of preventive maintenance are provided. According to COWI (2014), there may be an added cost (estimated in 10%) to take extra costs of possible reflective cracks into account for the semi-rigid pavements.

Some examples of costs and expected frequency of rehabilitation activities of flexible pavements (full depth repairs) are presented in Table 42. Some examples of costs and expected frequency of rehabilitation activities of rigid and semi-rigid pavements (full depth with partial removal of materials) are presented in for rigid pavements in Table 43. COWI (2014) provided some estimations of the rehabilitation of the entire rigid and semi-rigid pavements over 35 years (see Table 44).

Table 40: Costs and expected frequencies of preventive maintenance of flexible pavements.

Cost adapted from	Type	Truck Traffic AADTT	Maintenance	Thickness (mm)	First maintenance activity after construction (year)	Frequency after the first activity (years)	Cost [€/km·lane]
ARA (2011) [a)]	Motorway /highway	High	Milling and replace	50-90	32		15,500
		Medium	Milling and replace	40	32 20	 13-15	15,000 25,000
		Low	Milling and replace	40	20	13-15	25,000
	Secondary /regional roads	High	Milling and replace	40-90	20	28	19,000
		Medium	Milling and replace	40	20	28	14,200-19,000
		Low	Milling and replace	40	20	28	14,200
Hartmann, (2013)			Milling and replace		12		15,000

Motorway/highway (2 lane per carriageway):
High: AADTT 10000 Medium: AADTT 5000-7000 Low: AADTT 2500
a) Converted from CAD – 1.4781 exchange rate (July 2014)
b) Converted from DKK - 7.4557 exchange rate (July 2014)

Secondary/regional roads (1 lane per carriageway):
High: AADTT 1500 Medium: AADTT 500-1000 Low: AADTT 250
A lane width of 3.5-3.75 meters

Table 41: Costs and expected frequencies of preventive maintenance of rigid and semi-rigid pavements.

Data elaborated from	Type	Truck Traffic AADTT	Maintenance	% on 1 km of road	First maintenance activity after construction (year)	Frequency after the first activity (years)	Cost [€/km·lane]
ARA (2011) [a)]	Motorway /highway	High	Partial depth repair	5	12	12-15	11,000
		Medium	Partial depth repair	2-5	12	12-15	10,500-11,000
		Low	Partial depth repair	2-5	12	12-15	10,000
	Secondary /regional roads	High	Partial depth repair	5	25	12-15	7,000
		Medium	Partial depth repair	2-5	25	15-25	4,000-7,000
		Low	Partial depth repair	2-5	25	15-25	4,000
Federbeton (2010)	Motorway /highway	(Semi-rigid)	Cracking longitudinal joint Punch out and deterioration		13 10	7 10	7,700 5,180

Motorway/highway (2 lane per carriageway):
High: AADTT 10000 Medium: AADTT 5000-7000 Low: AADTT 2500
a) Converted from CAD – 1.4781 exchange rate (July 2014)

Secondary/regional roads (1 lane per carriageway):
High: AADTT 1500 Medium: AADTT 500-1000 Low: AADTT 250
A lane width of 3.5-3.75 meters

Table 42: Costs and expected frequencies of rehabilitation of flexible pavements.

Data elaborated from	Type	Truck Traffic AADTT	Maintenance	% per 1 km of road	First maintenance Activity after initial Construction (year)	Frequency after the first activity (years)	Cost [€/km·lane]
ARA (2011) [a)]	Motorway /highway	High	Full depth repair	10	18	27	31,000
		Medium	Full depth repair	5-10	18 48	27	30,000 3,000
		Low	Full depth repair	5	48		3,000
	Secondary /regional roads	High	Full depth repair	10	35		8,000
		Medium	Full depth repair	5	35		6,500-8,000
		Low	Full depth repair	5	35		6,500
Federbeton 2010	Motorway /highway		Full depth repair		28	28	25,000

Motorway/highway (2 lane per carriageway):
High: AADTT 10000 Medium: AADTT 5000-7000 Low: AADTT 2500

Secondary/regional roads (1 lane per carriageway):
High: AADTT 1500 Medium: AADTT 500-1000 Low: AADTT 250
A lane width of 3.5-3.75 meters

Table 43: Costs and expected frequencies of rehabilitation of rigid pavements.

Data elaborated from	Type	Truck Traffic AADTT	Maintenance	% per 1 km of road	First maintenance Activity after initial Construction (year)	Frequency after the first activity (years)	Cost [€/km·lane]
ARA, 2011 a)	Motorway /highway	High	Slab repair	10	25	12-15	18,000
		Medium	Slab repair	5-10	25	12-15	13,000-18,000
		Low	Slab repair	5	25	12-15	13,000
	Secondary /regional roads	High	Slab repair	10	25	12-15	13,000
		Medium	Slab repair	5	25	15-25	7,300-13,000
		Low	Slab repair	5	25	15-25	7300
Federbeton 2010	Motorway /highway		Slab repair			28	25,000
COWI (2014) b)	Motorway /highway		Full removal and replacement with new materials (rigid)				210,000
	Motorway /highway		Full removal and replacement with new materials (rigid)				175,000-225,000

Motorway/highway (2 lane per carriageway): High: AADTT 10000 Medium: AADTT 5000-7000 Low: AADTT 2500	Secondary/regional roads (1 lane per carriageway): High: AADTT 1500 Medium: AADTT 500-1000 Low: AADTT 250
a) Converted from CAD – 1.4781 exchange rate (July 2014)	A lane width of 3.5-3.75 meters
b) Converted from DKK - 7.4557 exchange rate (July 2014)	

Table 44: Cost of full removal and replacement of rigid and semi-rigid pavements (COWI, 2014).

Data elaborated from	Type	Pavement	Maintenance	First Activity after initial Construction (year)	Cost [€/km·lane]
COWI (2014) b)	Motorway /highway Secondary /regional roads	Rigid	Full removal and replacement with new materials	>35	210,000
	Motorway /highway Secondary /regional roads	Semi-rigid	Full removal and replacement with new materials	>35	175,000-225,000

3.3.2.2.3 Cost of adaptation to climate changes

Finally, costs of adaptation to climate changes due to rains, river floods, snows and evaluated by JRC, EC (2012b) are also reported in Table 45. It should be noted that they can represent a not-negligible percentage of the total expenditure for maintenance.

Table 45: Costs of extreme weather induced damages (JRC, EC, 2012b).

	Infrastructure spending (million €/yr)			Extreme weather induced damages (million €/yr)					
	Total	Maintenance	Investment	Weather costs of which		Weather costs-snow	Total rain and snow	Total	% maintenance costs
				Rain	River floods				
Alpines Regions	1138	448	691	43	4	16	59	59	13.2
UK& Ireland	12942	5534	7408	59	7	17	76	76	1.4
Eastern Europe	10711	3377	7334	29	20	74	103	103	3
France	12835	1338	11497	133	9	25	158	158	11.8
Iberian Peninsula	10094	923	9171	86	7	1	87	87	9.4
Mediterranean	12814	10095	2719	53	13	1	54	54	0.5
Middle Europe	7018	1901	5117	73	13	43	116	116	6.1
Scandinavia	5666	2398	3269	153	7	71	224	224	9.3
EU 27	73218	26014	47206	629	80	248	877	956	3.7

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ANNEXES
Annex 1 - Road pavement layer system

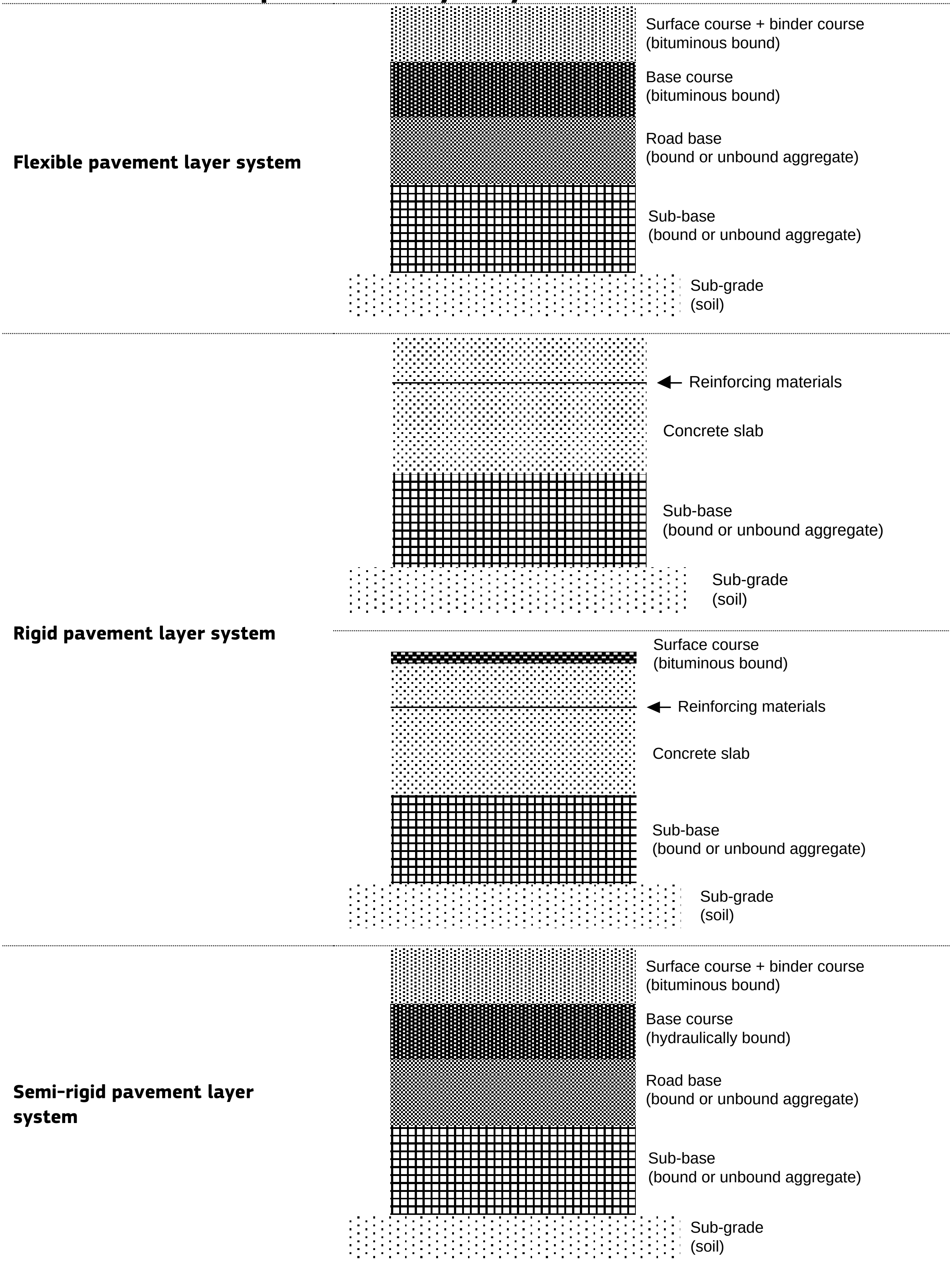
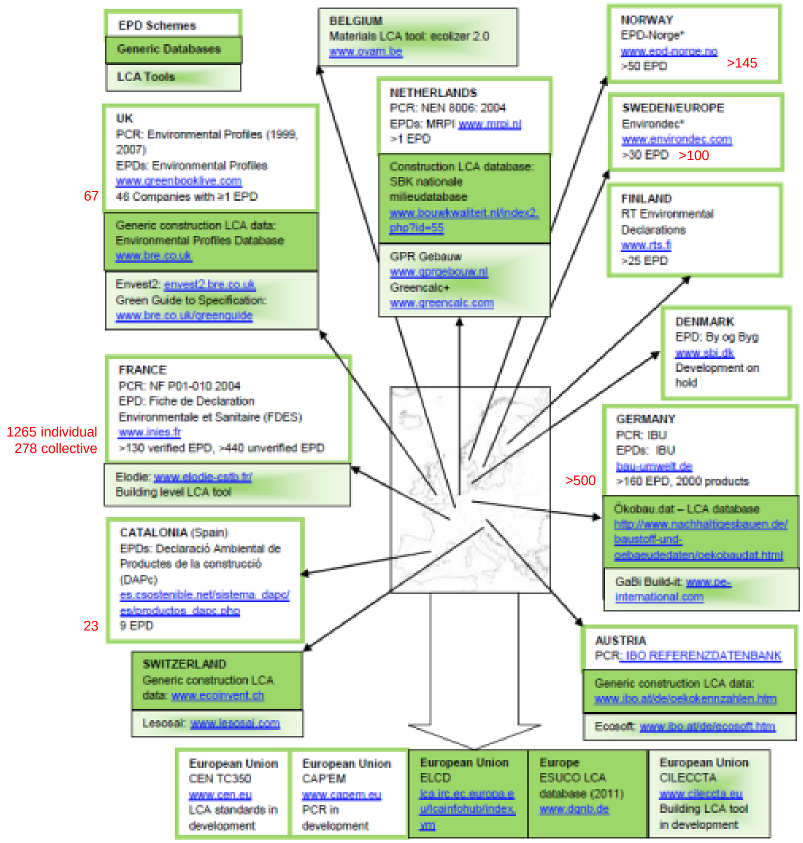


Figure A 1: Road pavement layer systems.

Annex 2 - Life cycle assessment methods

EPDs schemes

Many European countries, including France, Germany, the Netherlands, the Nordic countries and the UK, have developed national PCR schemes regulating the use of EPDs (see Figure A2).



EPDs numbers correct as of October 2010 – EPDs numbers updated as of July 2014 are highlighted in red

Figure A 2: National LCA schemes using EPDs according to the CPA guide (CPA, 2012).

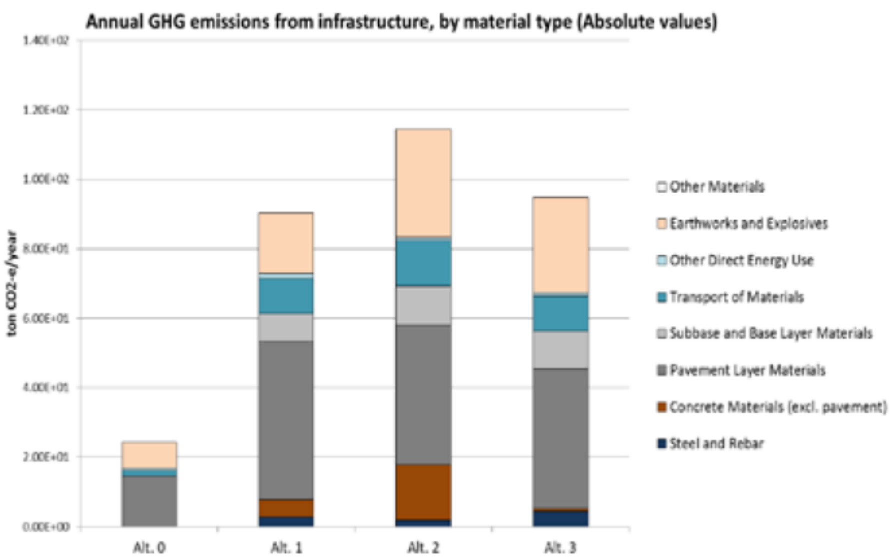


Figure A 3: Share of annual GHG emission for the different materials in road elements according to the annual GWP evaluated for 4 different road alternatives in the LICCER project.

Annex 3 - Additional information on HMA, WMA, HWMA and CMA

According to the results of the preliminary report, information on WMA/HWMA/CMA used in road construction is proposed as following in comparison to HMA. The environmental impacts of these materials are now evaluated by means of the holistic LCA approach over the life time of the road.

Traditionally, asphalt is referred to what is known as a "hot mix" process, the product being referred to as **HMA** (140-190°C). Where asphalt is specified in road construction, there exist a number possibilities to reduce the environmental impact associated with its production. These can be by using a lower temperature mixing process such as **WMA** (100-140°C), **HWMA** (70-100°C) or **CMA** (<60°C) (EAPA, 2007; D'Angelo *et al.*, 2008; EAPA, 2010; Capitão *et al.*, 2012; Rubio *et al.*, 2012; Blankendaal *et al.*, 2014). The Figure A 4 below is internationally often used to show the differences between HMA/WMA/HWMA/CMA. The classification is to some extent artificial and currently there is also no definition given by CEN TC227.

Not only do lower temperature mixing processes save energy, they have been associated with significantly lower energy consumption and VOC, PAH, CO, SO_2 and NO_x emissions, which is important both from an occupational health and safety and an environmental point of view (EAPA, 2010; D'Angelo *et al.*, 2008; Wayman *et al.*, 2012).

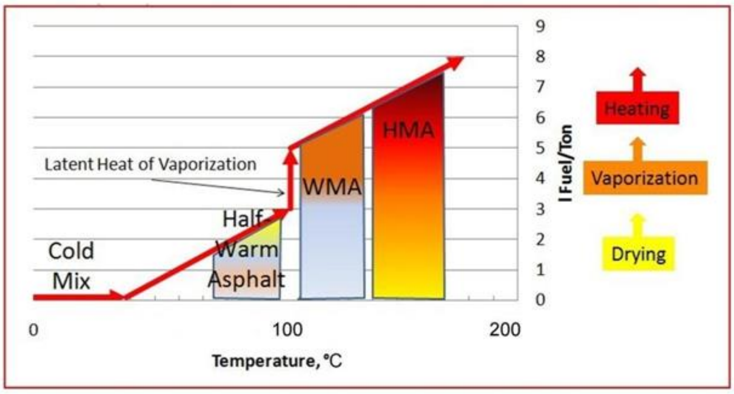


Figure A 4: Classification by temperature Range (approximate values).

According to the market analysis, WMA is the most widely used lower temperature option but still only accounted for 2% of the total production of bituminous mixtures in the EU (EAPA, 2012). Nonetheless, the trend in employing WMA is increasing, for example in France the WMA production increased by 5 times from 2008 to 2012 (up to 7.3% of total French asphalt production). Due to the low market share of WMA (and even less for HWMA and CMA) there may be a lack of suitable experience with such mixtures that would impede making such criteria broadly applicable.

Agentschap Wegen en Verkeer (2012) suggests that HWMA emits from heating up to 3-9 $kgCO_2/t$, WMA emits up to 16-18 $kgCO_2/t$, HMA emits up to 18-22 $kgCO_2/t$.

In terms of technical performance, there is a lack of long term experience with WMA, HWMA and especially CMA (in the latter case particularly for highways and motorways) although results with WMA seem comparable to HMA (Capitão *et al.*, 2012). Stakeholders generally supported considering WMA/HWMA/CMA as a possible criterion area, as long as technical requirements for a given application are met and durability guaranteed. They have indicated that experiences (both in Europe and USA) from the last 5-10 years suggest that HMA and WMA/HWMA have equivalent performances. Successful implementations have been completed in medium/high traffic flow roads in some MSs, such as Spain and France. Therefore, it seems that WMA has similar performance as HMA, at least on the short term and in relationship to the specific mixing technique. For long term performance, there are less data available. However, it has to be considered that HMA may be required by type of asphalt mixture, job site, weather conditions (paving season), *etc*. Therefore, the technique used is *fit for purpose*, *i.e.*, for different projects there will be different *best preferred solutions.* A stakeholder has pointed out that WMA technologies have been shown to be improved thanks to hydrated lime addition.

CMA is a different mix type than HMA/WMA/HWMA, thus there are situations where its use is not equivalent to the others. CMA is only suited for low traffic roads, due to technical limitations and durability considerations, and not for motorways.

Annex 4 - Guidance on materials with higher recycled content commonly used in road construction

According to the scenario assessment for resource efficiency in 2030 (EC, 2014) and to the results of the preliminary report, guidance on materials with higher recycled content that are commonly used in road construction is proposed as follows. After the 1st AHWG meeting it has been decided to evaluate the environmental impacts of materials by means of the holistic LCA approach over the life time of the pavement.

Reclaimed asphalt pavement (RAP)

A method of reducing the environmental impact of asphalt is to use RAP, which is produced by milling the overlay or demolishing the surface and base courses. It is defined according to EN 13108-8 and includes waste from mixing operations. It can be re-used by adding directly to the asphalt mixtures along with new aggregates and new bitumen (recycling). RAP can also be used as recycled aggregates in road base material, being stabilised with bitumen emulsion and/or binders (down-cycling). It can also be recycled as an unbound material in the road sub-base (down-cycling). In some MSs, RAP is not considered as waste as long it is re-used within the domain of asphalt sector.

Today in Europe, around 56 Mt/y of RAP are produced and more than 85% is re-used back into pavement materials (EAPA, 2013). Stakeholders have underlined that in some MSs, recycling of RAP reaches almost 100% and only minor amounts of materials are landfilled or destroyed. In the Netherland, landfilling of RAP is forbidden.

The EU research project Re-road (http://re-road.fehrl.org/) focused particularly on the analysis of end of life strategies of asphalt pavements (Kalman *et al.*, 2013). According to the outcomes of this project, in Europe the experience in reusing RAP in new asphalt production is well consolidated, even if there is a significant variation in the MSs and the consequence is that nowadays a large amount of demolished asphalt pavement is still down-cycled as unbound granular material in the sub-base layers. From a LCA point of view (Wayman *et al.*, 2012), the main benefits coming from the re-use and recycling of RAP are related to avoiding the need for bitumen production. Results demonstrate that greater benefits are achieved by means of bound RAP recycling rather than unbound in the sub-base course.

According to EAPA (2005), RAP can be recycled in new asphalt mixes in:

- off-site stationary plant, by means of:
    - hot mix recycling, in which RAP is preheated in a separate dryer or the same dryer of natural aggregates. In cold method, RAP is heated through the contact with heated aggregates; *or*
    - cold mix recycling, recent technologies in which foamed bitumen and bitumen emulsion are combined with RAP.
- on site recycling, by means of:
    - hot mix recycling using techniques like Road train, Reshape, Repave and Remix; or
    - cold mix, similar to the previous one except to the way bitumen is added.

Stakeholders have pointed out that in some MSs, RAP is always transported off-site to a stationary plant and that on-site re-use is not common. Therefore, requiring that all RAP should be re-used on-site during maintenance might lead to inefficient operations and excessive energy consumption. Moreover, not all RAP can be used for mixtures like porous asphalt and SMA because of the requirements for the grading of the mixture required. As discussed in section 2.3.1, WMA has a high energy savings potential, and even more so with the inclusion of a percentage of reclaimed asphalt.

There is no technical limit on RAP content in new asphalt mixtures as long as adequate performance is achieved. However, it is a common practice to set maximum values in order to guarantee the durability of asphalt mixes in the long term. The defined optimum content of RAP in asphalt mixtures varies widely from country to country, from 7 to 50% (up to 66%) by mass (Kalman *et al.*, 2013). On average, Western European has 40% RAP content in HMA/WMA, Eastern European 6% (BIOIS, EC 2011; Blankendaal *et al.*, 2014). As discussed in section 2.3.1, stakeholders pointed out that a minimum recycled content does not appear to be necessary to stimulate the market, also considering the current high cost of bituminous binder.

Concrete and cement

Concrete is a fundamental component in road construction that can be used in road base, binder courses and surface courses. It is a composite material which on a weight percentage basis consists of approximately 5-7.5% water, 10-15% cement with the remainder being aggregates (coarse and fine, following the EN 12620 standard).

By far the most common cement used in concrete, either in road construction or any other application, is Portland cement. Although cement only accounts for 10-15% of concrete mass, it is by far the most significant factor in terms of the environmental impact of concrete (Stripple, 2001). To produce 1 tonne of Portland cement, approximately 1.5t of raw materials (mainly limestone and clay) are fired in a rotary kiln at temperatures of around 1450°C. Approximately 0.55t of the raw material is lost as CO_2 from limestone decarbonation or as kiln dust. The remaining 0.95t forms Portland cement clinker, which is then ground together with 0.05t of gypsum to form 1t of CEM I type Portland cement.

In Europe, efforts to reduce the environmental impact of Portland cement manufacture via improved kiln technology and the use of alternative fuels for kiln firing have reached an advanced stage in many Member States. The simplest remaining option is to reduce the "**clinker factor**". The CEM I type cement mentioned in the previous paragraph can be considered to have a clinker factor of 0.95 (95% by dry mass clinker). However, decades of research have revealed that cement clinker can be partially replaced by any one of a number of Supplementary Cementitious Materials (SCMs). These materials are either industrial by-products (*e.g.*, coal fly ash, blast furnace slag) or natural materials (*e.g.*, limestone, natural pozzolana) and in all cases possess usually a much lower embodied energy than Portland cement clinker itself. A stakeholder suggested that the lower embodied energy depends on the allocation methods used by the SCMs producers and that this rules should be specified by the contracting authority in the ITT. Regulations regarding the use of SCMs in the Portland cement to be marketed in the EU are covered by EN 197-1, EN 15743 (Supersulfated cement) and EN 196 series.

CEM I type Portland cement (95% clinker) is today only one of 27 different categories of normal cement described in EN 197-1. All of the remaining categories are split into four types (CEM II, CEM III, CEM IV and CEM V). These categories specify reduced clinker contents, and thus reduced environmental impacts. Between the categories, clinker can be replaced by ranges from 6% up to 55%, or specifically in the case of blast furnace slag, up to 95%. Already in the EU cement market sales of CEM II are higher than CEM I. In terms of availability of SCMs, it is possible that in some regions, certain materials will not be available. However, in all cases, blended cements using limestone as a SCM will be feasible since this is the primary raw material used in Portland cement clinker manufacture. Furthermore, cement blended with limestone should not only have lower environmental impact, but be considerably cheaper to produce. See also the results of the study reported in section 2.3.1 (Blankendaal *et al.*, 2014).

Stakeholders underlined that many SCMs are commonly used in the Netherlands (more than 60% of all concrete). In Germany concrete surface courses with slag cement have been successfully utilised, even though it is not yet a common practice.

Requirements on concrete are covered by the standards EN 206 and EN 13877. Stakeholders underlined that EN 206 is not harmonised and so relevant application rules are defined on a national basis. For example the German DIN 1045-2 excludes cements CEM III/C with slag contents >80% from nearly all applications. Also for CEM III/B cements some restrictions are defined. Moreover, some highly blended cements are technically not allowed for the construction of durable concrete pavements. In the document we will therefore make reference to EN206 and relevant national legislations.

In conclusion, the recycled content in concrete could be evaluated both for the different supplementary used in cement production and for recycled aggregates used in mix design. In the first case, the % range of clinker derived from its category classification has to be used.

Recycled and secondary aggregates

Recycled and secondary aggregates have been defined in paragraph 2.3.1. According to the literature review, the use of recycled and secondary aggregates can play a key role in the delivery of environmental policy and GPP objectives (ETC/SCR, 2009). In terms of C&DW as recycled aggregates, the Waste Framework Directive has set a target of at least 70% recycling by 2020. Road construction represents an excellent opportunity to use recycled aggregate (from C&DW) and secondary aggregates, *i.e.*, manufactured aggregates and/or extraction by-products in unbound and bound application.

Recycled products and materials complying with the CPR must be considered equal to products based on primary materials (WRAP, 2005). For bound or unbound aggregates, the main standards are EN 13242 on aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction and EN 13285 on unbound mixtures. For bound applications in road construction, EN 13043 is the standard for aggregates for bituminous mixtures, EN 12620 for aggregates for concrete and EN 13139 aggregates for mortar. According to the above mentioned standards and to the EN 16236 on the evaluation of conformity of aggregates, geometrical requirements (as grading, fines content and quality, shape, *etc.*), physical requirements (as resistance to fragmentation, particle density and water absorption, bulk density, frost-susceptibility *etc.*), chemical requirements (as petrographic description, chloride content, sulphur containing compounds, organic substances, carbonate content, *etc.*) are tested in the initial Type Testing and Factory Production Control.

Chemical/environmental properties of recycled/secondary aggregates relate to soluble substances or elements, which may leach into soil, ground or surface waters and pose adverse environment impacts. Several Member States have defined limiting values in terms of chemical contamination in relation to possible leachate (following different standard according to national legislations, as underlined in Tables 5.2.a-b-c-d-e and 5.3.a-b-c-d-e of EC, JRC 2014). These often have an associated labelling or classification schemes and/or quality assurance to certify that the recycled end product complies with these limits (BRV, 2007a, b, c; standard "LAGA 20"; Quality Protocol for Aggregates DEFRA WRAP, 2013). Guidelines are often provided on the acceptability of secondary materials in road construction (Setra, 2011; Setra, 2012a and b; Trafikverket 2011). Further use of by-products has to be lawful, according to all relevant products, environmental and health protection requirements (art. 5 of the WFD). Stakeholders also pointed out that in many MSs the use of secondary materials in construction is well structured and legal requirements are set on quality and leaching.
However, should the RAP be instead used in the road base as unbound aggregate, it would be considered as recycled aggregate.
According to BIOIS, EC (2011), coarse aggregates can be used for road-base, sub-base and civil engineering applications. A Finnish research has found that recycled concrete in the sub-base and base layers can allow the thickness of these layers to be reduced due to the good bearing properties of the material.

Annex 5 - Additional background technical aspects on water and habitat conservation

Watercourse pollution during road construction

During the construction of new roads, due to the quantity of earthworks involved and the alteration of natural slopes and flow-paths for drainage, there is a high risk of erosion and massive sediment transfer to local watercourses. These should be avoided just as much for the technical problems caused by embankment erosion as for the environmental impact of silting up of watercourses.

Clearly not all road projects present similar degrees of risk of watercourse pollution. The main factor is the scale of the works to be carried out, closely followed by proximity to local watercourses. Even where watercourses are not so close by, erosion can be a big problem if the sediment is transferred to existing drainage systems, which will quickly block up.

Risks can take place during the construction phase due to earthworks and the formation of sloped embankments and also during the use phase if embankments are to be vegetated but are very exposed after construction due to the fact that vegetation is yet to establish itself well.

A number of different technical approaches can be taken to reduce the risk of sediment transfer to local watercourses (or existing drains), some of which are illustrated in Figure A 5.

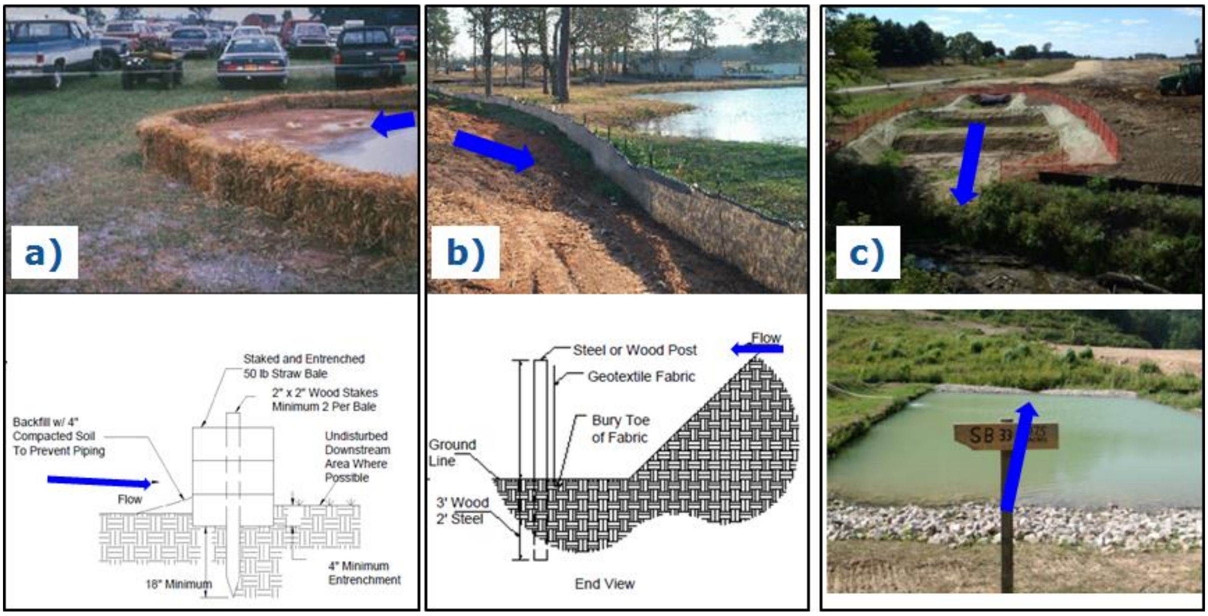


Figure A 5: Example of measures that can be taken to control sediment erosion and transfer to watercourses/drainage systems using temporary measures; a) straw bale filter dykes and b) geotextile silt fences; or semi-permanent/permanent measures; c) sediment ponds.[40]Blue arrows indicate flow paths.

It should be noted that all of these approaches can completely fail if not constructed properly and so simply implementing the measure is not sufficient. It is vital to implement the measures correctly, which would require onsite verification during construction works.

In very dry climates, it may be necessary to cover with tarpaulins and/or dampen loose soil and other fine materials that are stored onsite in large quantities or simply exposed at the works surface for any length of time.

40 Photos and images adapted from: http://www.dot.state.oh.us/Divisions/ConstructionMgt/OnlineDocs/2013MOP/Supplements/SS_832.htm and http://water.epa.gov/polwaste/nps/urban/upload/2003_07_24_NPS_unpavedroads_ch6.pdf

Watercourse pollution during the use phase of the road

During the use phase, stormwater is drained from the road surface by gravity. As it reaches the drain system it may pick up a number of pollutants and transfer them to the local watercourse via drainage outflows. The most commonly considered pollutants from road surfaces are:

- Zinc (Zn) and Sulfur (S) in tyre particles in concentrations up to 9,000mg/kg and 12,000mg/kg respectively (Kreider *et al.*, 2010);
- Highly variable loads of elements such as Sodium (Na), Potassium (K) and chloride (Cl), due to the use of road grits when snow/ice on roads is expected;
- Polycyclic aromatic hydrocarbons (PAHs), from atmospheric deposition of exhaust gases / exhaust particulates (Dong and Lee, 2009);
- Oils, lubricants and aromatic compounds from vehicle leaks;
- Metals from brake pad wear such as Copper (Cu) (Hulskotte *et al.*, 2006), Zinc (Zn) (Armstrong, 1994) and where stainless steel brake pads are used, Iron (Fe), Nickel (Ni) and Chromium (Cr) in road particles;
- Precious metals Platinum, Palladium and Rhodium (Pt, Pa and Rh) from catalytic converters can be found in road dust in concentrations up to around 1mg/kg (Pritchard *et al.*, 2009);
- Untreated raw municipal sewage via combined sewer overflows during heavy rain events.

Regarding the last type of pollution in the above list (untreated sewage), it is obvious that sewage does not originate from the road. In many areas, the practice of connecting drainage systems to municipal sewers was initially seen as an advantage for helping flush out the sewers periodically, but now in many of these areas, due to increased urbanization, so much surface drainage enters the municipal sewer that problems with sewerage backflow can occur, with raw sewage gushing out of manholes in streets during heavy rain or via storm surge tanks and overflows used to protect sewage works from excessive influent flow rates. All of these overflows run directly to local watercourses. Thus by connecting road drainage to the sewerage network, intense peak flows of stormwater from roads can lead to excessive flows in the sewerage mains and subsequent overflows into local watercourses. It must be noted that this situation can be completely avoided if the road drainage system is **not** connected to the mains sewerage system. The differences between combined and separate drainage systems is clearly illustrated in Figure 3.47 of the Preliminary Report for Road Construction GPP (page 169).

Many of the pollutants from the list above are associated with solid particles and so the removal of these particles results in the removal of the pollutant. Traditional piped drainage systems can act as unwitting sediment traps during low flow velocities and dry weather. This is undesirable because the accumulated sediment will partially block the pipe, may impair the performance of the pipe and lead to unpleasant odours. Furthermore, the sediment cannot be considered as truly diverted from the receiving watercourse because it will eventually be flushed through the pipe at some point.

To prevent sediments building up in the drainage pipes or reaching the watercourse, a traditional approach has been to design sediment traps at road gully inlets. The performance of gully pots is governed by gravity and the settling velocity of any particular particle in a gully pot will approximate to Stokes law. Practical experience has shown that performance is inversely proportional to inflow rate and the particle removal efficiency will depend on the size and specific gravity (density) of the particle. According to Bolognesi *et al.* (2008) the particle sizes of trapped solids in road gully pots can range from 53µm to 4mm, with median values in the range 100 to 600µm. The same authors report specific gravities of road surface drainage particles in the range of 1.9 to 2.8. This implies that gully pots are not particularly useful for the removal of clay and silt sized particles (*i.e.*, <53µm). An example of a road gully pot cross section is shown in Figure A 6). Clearly gully pots gradually fill up with time and have to be inspected regularly and then periodically removed, emptied and returned as part of routine maintenance.

Other pollutants from the list above are oils and lubricants from vehicles. These pollutants are a particular concern around motorway service stations and petrol stations anywhere due to continued minor inputs of oils and the potential for major inputs caused by accidental spillages. Pollution from oils in low velocity watercourses can be highly visible via the formation of slicks on the surface. Traditionally oil interceptors have been used and follow the physical principle that oils will float on the surface of water. An example of an oil interceptor is shown in Figure A 6).

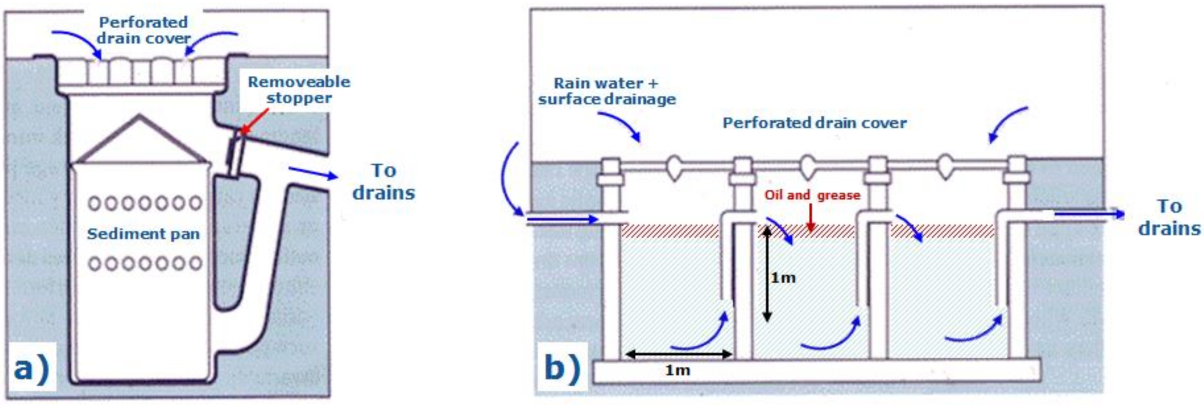


Figure A 6: Cross-sections of typical pollution control devices used at the inlets to traditional drainage designs; a) gully pot sediment trap and b) an oil interceptor (adapted from Emery, 1986).

The pollution control devices that are shown in Figure A 6 are underground devices installed as part of civil works and will be part of concrete structures. These devices simply contain the pollutants which then have to be physically removed and appropriately disposed of.

During the last few decades there has been growing interest in more holistic solutions to road drainage that include the potential for in-situ treatment of certain road pollutants, possible habitat creation and the reduction of flood risk in downstream areas. The general term SuDS (Sustainable urban Drainage Systems) has been coined relating to drainage systems in urban areas but the same principles can apply to rural areas. The general technical aspects of SuDS are summarised in pages 170-175 of the preliminary report for road construction.

SuDS drainage components can offer the potential to filter out large debris by the use of gravel filled trenches with perforated pipes laid at the bottom. Components such a grass swales also offer a degree of filtration as well as the potential for sediments to be incorporated into the underlying soil media and also the potential for microbial degradation of organic pollutants. The use of sedimentation basins or artificial wetlands can provide effective removal devices for sediments. However, if suitable upstream pre-filtration is achieved in the drainage system, these can instead provide high quality drainage water and actually provide valuable habitat for insects and local wildlife.

Basically a number of components can be introduced into the drainage system, often at the inlet points, to achieve pollutant removal or reduction in the drainage water. These components can be hard engineered (*i.e.*, concrete and/or plastic based) or soft engineered (*i.e.*, SuDS which are soil/plant and/or gravel based). It is possible to have systems that combine both hard and soft engineered components. The potential to introduce soft-engineered SuDS type drainage components will depend on the nature of the site but is almost always an option due to the variety of SuDS components that have been developed and the fact that drainage systems can extend far beyond the site which it actually drains. GPP award criteria could thus favour the softer engineering solutions over the more traditional hard engineered ones.

Flood risk mitigation during the use phase of the road

For river basins and sub-basins identified under the requirements of the EU Floods Directive (2007/60/EC) as being at a significant risk of flooding, flood mitigation actions must be taken which are to be laid out in flood risk management plans that must be published by all Member States by 2015.

The traditional approach to road drainage (and urban drainage in general) has been to ensure that the local site does not flood and that stormwater is rapidly conveyed off site. Such an approach is the polar opposite of what happens in natural environments where water is initially held on the surfaces of plants, then gradually infiltrates in to the soil and only in extreme storm events would sheet flow of water occur across the surface. To generalize, the average time in rainfall-runoff relationships for stormwater to reach local surface water-courses in urban areas is very much shorter than in greenfield sites, as illustrated in Figure A 7.

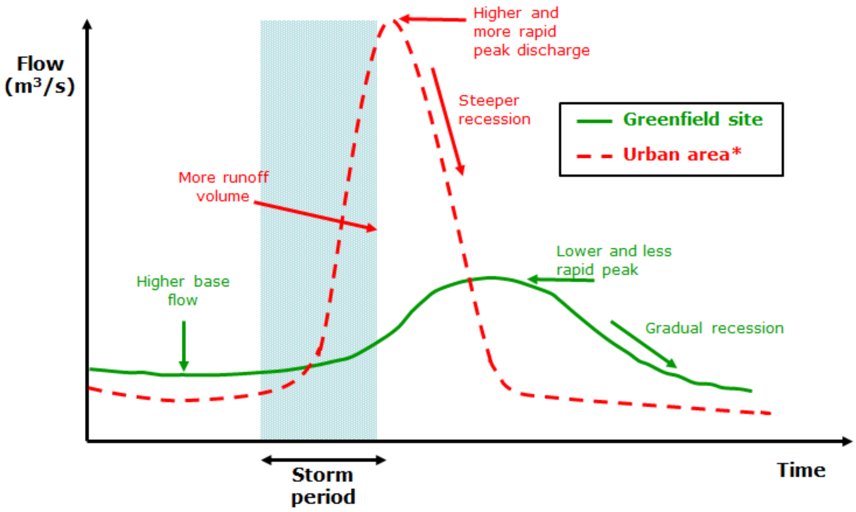


Figure A 7: Example of the differences in rainfall-runoff relationships in greenfield and urban sites. *denotes that it is an urban area with a traditional drainage system focused on rapid conveyance of stormwater offsite (adapted from CIRIA, 2007).

Figure A 7 also illustrates that peak flow rates in local watercourses are much higher when the surrounding area is urbanized – this can contribute to an increased risk of flooding in downstream areas, especially in poorly planned developments where urban areas now exist within natural floodplains. Another factor that contributes to the problem is uncertainty over future rainfall patterns due to climate change.

The problem of higher peak flow rates has gradually increased in line with urbanization and, coupled with more intensive rainfall in certain regions and poorly planned development, has led to major flooding in certain areas that have historically never been subject to flooding and also to floods on scales that are much larger than previously experienced. Road drainage infrastructure typically has a very long service life (50-100 years) and it is perfectly feasible that a drainage system designed based on current rainfall data is inadequate in 20 years' time if design does not take into account future upstream development and changes in rainfall pattern.

Predicting the future rainfall patterns and upstream development over periods of up to 100 years is an impossible task. A better approach is to ensure that drainage systems move away from the traditional rapid conveyance of water off-site to a more natural system where stormwater retention capacity is created and run-off patterns better approximate those of a typical greenfield site. Drainage systems with these properties will place less pressure on the wider drainage infrastructure, help reduce flood risk in downstream areas and may also contribute positively to the local aesthetics and habitat creation.

As with the drainage components for water pollution control, "hard engineered" and "soft engineered" components can be used and GPP award criteria should look to favour those proposals which incorporate more soft engineered components and help with improving the aesthetics of the site and potential habitat creation. It should be noted however that hard engineered solutions are typically ready to use once installed with minimal additional monitoring whereas the success of soft-engineered systems will depend on crucial factors such as good establishment of plant species or grass in swales, retention ponds and artificial wetlands and the correct choice of plant species for the climatic conditions and local wildlife.

The key design factor is the site runoff rate response to a defined storm event that should be specified by the procurer or planning authority. Storms are defined their intensity, duration and frequency of occurrence (return period). The intensity of a storm of particular duration and frequency can be calculated by creating a model using real historical rainfall data in a particular region to produce intensity-duration-frequency curves as shown in Figure A 8. Zhou *et al.* (2012) refer to models in place in the UK, Denmark and Germany while stakeholder feedback after the meeting confirmed that the Netherlands have such a model in place too. An example requirement for planning permission in an area considered at significant risk of flooding may be to have a drainage system installed that shows a rainfall-runoff relationship no different to that of an equivalent greenfield site for a 110 mm/h rainfall storm of 2 hours duration and 1 in 100 year return period (frequency). Due to uncertainty with climate change, some planning authorities now ask for the same requirement and simply add +30% or +50% as a safety margin to account for climate change uncertainty.

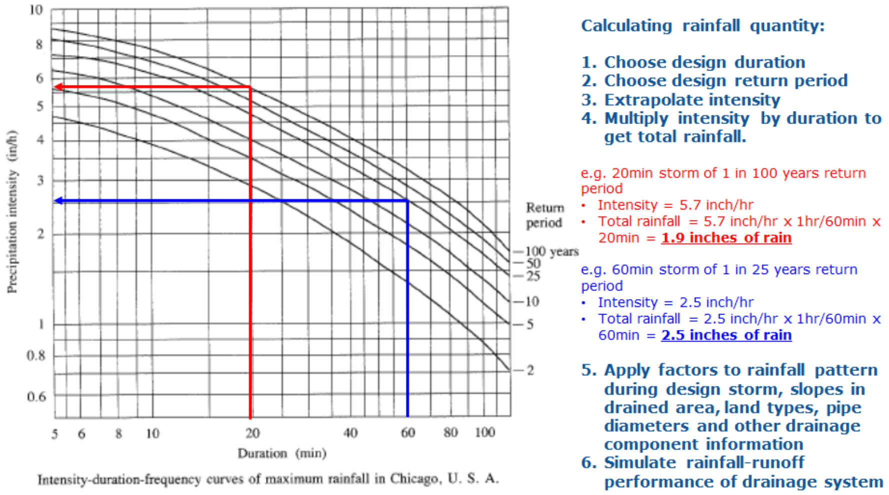


Figure A 8: Example of modelled rainfall intensity-duration-frequency relationships in Chicago (Zhou *et al.*, 2012).

Habitat creation and reducing the degree of habitat fragmentation

Road construction has a double negative impact on natural habitat: (i) direct habitat loss; and (ii) the fragmentation of the surrounding habitat. In terms of damage to wildlife, it is clear that the fragmentation of habitat is the greatest concern. The problems of habitat fragmentation may not be so obvious at the design stage or even during operation of the road and only tend to be noticed when medium-large sized mammals are repeatedly killed on roads. The technical and logistical challenges of taking remedial action on already constructed roads are considerable and will cost more, both in time and money, than if they were carried out during the initial road construction project.

During a new road construction project, the likely effects on land fragmentation and habitat loss should be covered under Strategic Environmental Assessments (SEAs) and Environmental Impact Assessments (EIAs). The contracting authority should be well aware of issues such as whether or not the road impacts on high conservation value areas and areas with rare and endangered flora or fauna. There are four general approaches which can be taken during planning regarding the impacts of road construction on habitats which are illustrated in Figure A 9.

Major planning decisions are out of the scope of GPP criteria since they will already be broadly agreed upon prior to permission for the project being granted and before any ITT would be published.

Where compensation or mitigation measures are requested in the project, there are important points to take into account during design, such as the appropriate use of fencing, slopes, path widths and vegetated pathways and other aspects which should be covered in the EIA.

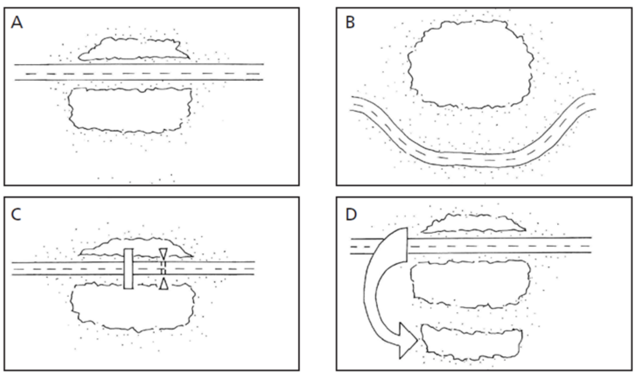


Figure A 9: Examples of A) fragmentation, B) avoidance, C) mitigation and D) compensation approaches to habitat impact during road construction (COST 341).

In cases where a need for creating a habitat corridor over or under an existing road is identified, then the ITT will be specifically focused on this and it is not within the scope of normal road construction or maintenance. Consequently it is considered that habitat fragmentation and corridor creation are outside of the GPP scope.

One area where habitat corridors could be potentially part of normal road construction is the design and construction of filter drains, gullies and culverts for road drainage. Filter drains and gullies could present traps for amphibians, insects and small animals. Some types of culvert may be very useful aid to fish, amphibians and small mammals crossing the road while others are potential death traps or complete barriers to these species. The wording of GPP criteria should encourage the use of the more species friendly culverts in tenders and make procurers aware of these options. Some examples of culverts, highlighting features that are important to easing the passage of small mammals are shown in Figure A 10 and for aquatic species in Figure A 11.

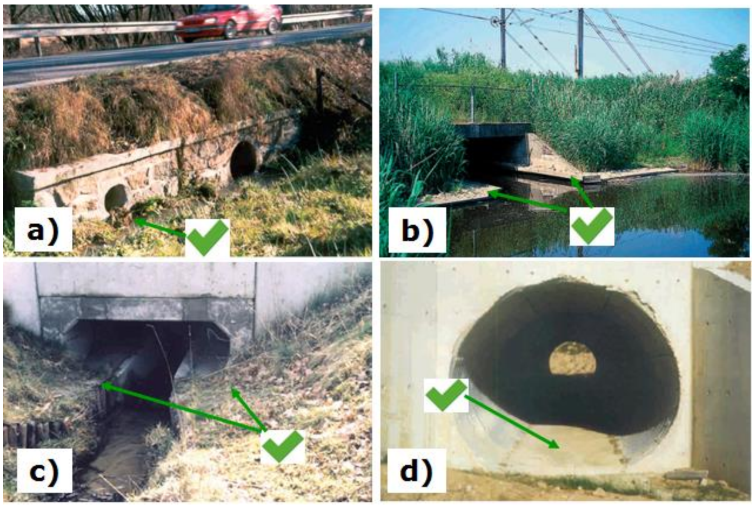


Figure A 10: : Examples of good culvert design to aid the passage of small mammals: a) a double culvert with one raised above the water level to allow for the passage of otters, who prefer dry crossings; b) retrofitted wooden walkways in a culvert in the Netherlands that are well connected to the dry embankment; c) prefabricated concrete culverts with integrated ledges in the Netherlands and d) example of a stormwater culvert in Spain made of corrugated steel where the ridges along the bottom section have been filled in with concrete afterwards to facilitate the passage of insects and small animals.

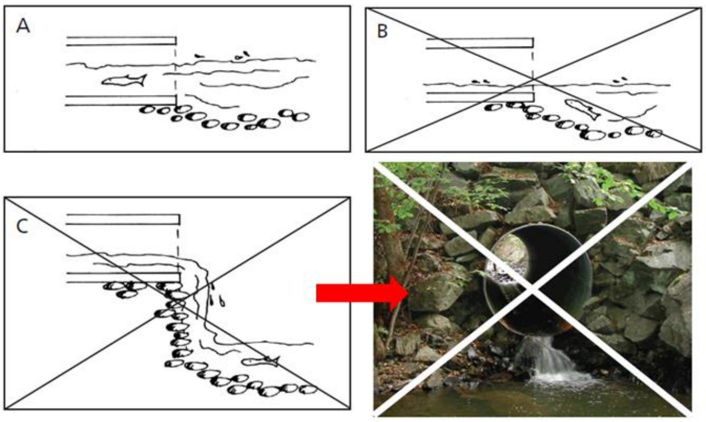


Figure A 11: **Examples of culvert placement that are A) good for fish migration upstream or B) and C) prevent fish migration upstream.**

It is clear that culvert design can aid or prevent the migration of species in a safe manner across the road. Where culverts are required for road drainage, with a little extra thought, these drainage channels can become potentially valuable migration routes for fish, amphibians and small animals. The opportunity to encourage such designs in GPP criteria should be used.

Annex 6 - Additional background technical aspects on noise

Technical aspects - Noise barriers

While low-noise road surfaces specifically reduce noise from road-tyre contact, noise barriers can restrict the propagation of noise from all three sources (engine train, road-tyre contact and aerodynamic) to defined receptor areas. However, in dense urban environments, noise barriers may be:

- not possible in areas where visibility across the road is required;
- not practical in areas where limited space is available or the area exposed to road noise is very large and includes tall buildings; or
- generally not very aesthetically pleasing, although it must be highlighted that noise barriers can be very well integrated into urban and rural environments with imaginative designs and may even contribute positively to the aesthetic aspect of the local area.

In the US, the use of noise barriers (or noise walls) is currently the only noise mitigation measure that will be considered and accepted by the Federal Highways Association (FHWA) in environmental impact assessments related to roads. The principal argument that the FHWA provides in support of this stance is that noise barriers can be reliably designed to provide accurately quantifiable noise reductions in defined receptor areas over long periods of time, unlike low-noise pavements, whose durability of performance has yet to be thoroughly investigated in the US.

Noise barriers can be made of many different materials and can be vertical barriers (for example made of wood, steel or concrete) or berm barriers, made of loose or stabilised soil stacked at a certain angle (see Figure 3.43 in the preliminary report for different barrier types).

In rural roads and motorways where land is available at either side of the road, it makes financial and environmental sense to use any excess soil from earthworks during construction in the form of landscaped earthen berm barriers. If climatic conditions permit, these berms could be vegetated to help improve aesthetics and the stability of the berm.

For a particular scenario, noise reduction using a noise barrier of a given material may be achieved in a more cost effective manner by taking into account the proper placement and structuring of the barrier as is highlighted in Figure A 12.

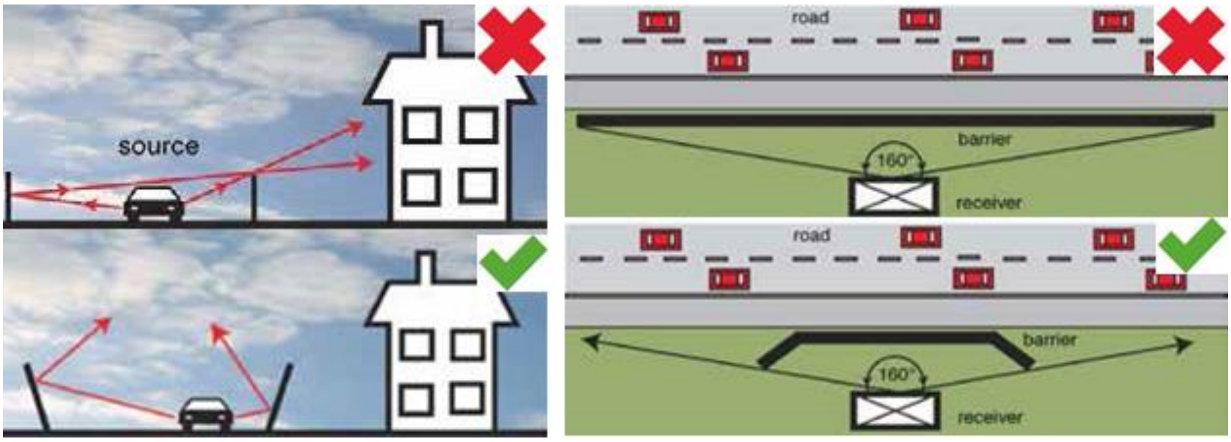


Figure A 12: Illustration of some different approaches to achieve more cost-effective (green tick) noise reduction by modifying noise barrier design. (Pigasse and Kragh, 2011).

The solutions in Figure A 12 illustrate on the left hand side how installing the barriers at a slope can reduce the degree of reflection of sound from one barrier to receptor areas on the opposite side of the road. On the right hand side of Figure A 12, the length of noise barrier required to protect a defined receptor can be reduced significantly by tapering the edges. Another potentially more cost effective and practical solution when it is decided that a noise barrier should be increased in height is to consider adding a horizontal plate on top, creating a "T" type formation.

The key environmental impacts of the noise barriers are related to the embodied energy and durability of materials used in their construction. It is difficult to compare steel, which has a high embodied energy, long lifetime and which is economically attractive to fully recycle at the end of life with wood, which has a much lower embodied energy but potentially a much lower durability and that is difficult to recycle properly and will most likely end up being downcycled as wood fibre or burned in energy recovery facilities.

In terms of life-cycle costs, by a distance the best performance is achieved with earth berms according to Morgan *et al.* (2001), with the most expensive being absorbing aluminium plates. The use of absorbing barriers reduces the problems due to reflection although such barriers are almost inevitably more expensive than none absorbing barriers. Recent research has suggested that irregular edges at the tops of vertical noise barriers could improve noise reduction in receptor areas but further work is needed to better understand this phenomenon.

Although the benefit of vegetation in noise barriers has no fully proven benefit on further noise reduction, it is obvious that it would improve the aesthetics of the barrier and may bring other benefits such as improving air quality and avoiding need for graffiti removal *etc*.

A noise barrier can be defined as the "barrier insertion loss", which compares the sound pressure at a defined receptor point when a defined sound source is present and how this pressure changes when a barrier is placed in between the sound source and the receptor point. At the design stage, it would be possible for a procurer to specify the use of a noise barrier with a particular insertion loss and a minimum durability of performance. A minimum insertion loss of 10 dB should be a pre-requisite for noise barriers. EN 1793-1 is the laboratory testing method for absorbing noise barriers and for highways and it is generally recommended that a level of at A3 or A4 should be specified (Parker, 2006).

The actual noise reduction performance achieved in site at a defined receptor area will then depend on the precise location of the barrier, its correct placement, the height of the barrier and the specific nature of the sound source (*i.e.*, single carriageway, dual-carriageway, three-lane motorway, *etc*.).

This can later be assessed in-situ by the following methods described in CEN/TS 1793-5, EN 1793-6 and EN 14389-1.

Other important aspects of noise barriers are covered by standards EN 1794-1 and -2 although these relate to the wind load, static load, fire resistance and other technical properties that may not be considered as true environmental criteria and thus outside of the scope of GPP criteria.

Technical Aspects – Low-noise pavements

Road-tyre contact noise that is generally considered as the dominant source of noise when vehicle velocities exceed 50 kph (Donovan and Rymer, 2003). Therefore it is particularly pertinent to consider low-noise surfaces in road sections with a posted speed limit of 50kph or higher.

The main mechanisms of noise production during road-tyre contact are as represented in Figure A 13.

It should be added that in addition to the sources of sound emission from road-tyre contact listed above, there are a number of other physical phenomena which can enhance these sound emissions such as the horn effect and other types of resonance and vibrations. It is estimated that further improvements in tyre properties could lead to reductions of 1-2 dB in noise emissions but it must be emphasised that tyres are well outside of the scope of this GPP project. So this technical background will only focus on relevant road surface properties.

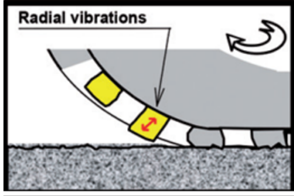
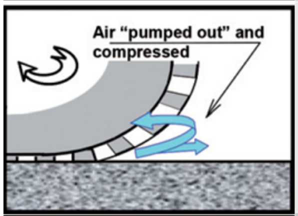
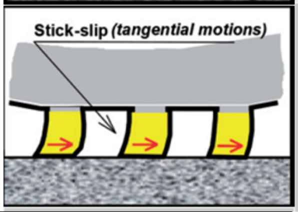
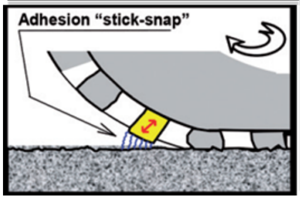
Illustration	Description	Relevant properties
	Tyre treads are less stiff than road surface so deform when sandwiched between car weight and road surface and expand again later. Analogous to hundreds/thousands of small hammer stokes per second.	• Road surface texture • Road surface stiffness • Tyre pressure • Tyre tread design • Tyre rubber
	Air trapped in tyre treads is compressed when the tread is in direct contact with the road surface and pumped out once the tread is open to the air. Analogous to the noise of air rapidly forced out when clapping hands.	• Road surface texture • Road surface stiffness • Road surface porosity • Tyre pressure • Tyre rubber • Tyre tread design
	Tyre treads in contact with the road surface are continually subject to forces, the balance of which in any particular moment for each tread will determine if the tread "sticks" or "slips", an analogous situation is that of sneakers on a basketball court.	• Road surface texture • Road surface stiffness • Tyre pressure • Tyre rubber • Tyre tread design
	The effect is analogous to that of a suction cup on a smooth surface when air is pushed out.	• Road surface texture (

Figure A 13: Summary of the main noise generating mechanisms during road-tyre contact (adapted from Rasmussen, 2007 and WRA 2013).

Technical Aspects - Techniques of assessing the noise performance of road pavements

The three main direct methods of measuring noise emissions from a road are:

- The Statistical Pass By (SPB) method, as defined in ISO 11819-1, involves taking measurements from acoustical instruments placed at a defined point from the road. The SPB results are taken from random passing vehicles at measured velocities. This data gives a good approximation of real noise experienced at the road side, but is limited in the sense that it is time consuming and can only be taken from one point on the road and so will probably not be representative of the entire road section.
- The Controlled Pass By (CPB) method, which is basically the same as the SPB method but using standard reference vehicles and speeds when taking SPB measurements. This produces better quality data due to the removal of random factors such as simultaneously passing vehicles, vehicle-specific variations such as engine sizes and tyre pressures and also variations due to different driving styles (gear selection, *etc*.). CPB may only be practical to measure prior to road opening and still suffers from the same limitation of SPB in that it is a spot measurement.
- The Close Proximity Method (CPX), as defined in ISO/CD 11819-2, involves the use of acoustic instrumentation mounted next to a tyre on a specially designed vehicle that monitors the noise levels along the length of a road section. This method has the advantage of being able to test large lengths of road relatively quickly and is a truer reflection of the noise generated from the tyre-road interaction.

The SILVIA project carried out in the EU sets out a framework that can be used to classify the noise emission performance of a particular road surface as shown in Table A. 1.

Table A. 1: Noise testing framework for road surfaces set out by SILVIA.

	Method of assessment for different road surfaces		
Label identification	**Dense graded**	**Open graded**	
	Rigid	Rigid*	Elastic
Label 1 (preferred)	SPB CPX	SPB CPX	SPB CPX
Label 2	SPB Texture	SPB Texture Absorption	SPB Texture Absorption Mechanical Impedance

* rigid surfaces are defined as normal asphalt (dense and open graded) and concrete.

The standard procedures for SPB and CPX are as mentioned above. The use of CPX is the most directly relevant test method in relation to noise emissions however, if such equipment is not available, SILVIA provides alternative tests that can be used as a proxy to expected noise emissions and that can also be measured along the length of test road sections.

In cases where texture measurements are used to supplement SPB data, SILVIA refers to the use of static and mobile tests for texture analysis according to ISO 13473-1, ISO 13473-3 and ISO/CD 13473-4. If absorption measurements are to be used, then the extended surface method defined in ISO 13472-1 should be used. With the measurement of mechanical impedance, no international standard method yet exists and the reproducibility of current methods has yet to be demonstrated.

In Appendixes A, B and C of the SILVIA report, extensive guidance is provided as to how to treat data to determine final values for the performance of the road, how to ensure monitoring equipment is adequately calibrated and a step by step approach as to how to apply the measurements to a real life road section.

Despite the outputs from SILVIA in 2006, no standard approach exists for checking the conformity of pavement systems with declared noise performance at the EU level yet. Approaches taken by some different Member States are described in section 2.5.1.

Technical aspects - Aggregate grading and its relationship to porosity in low-noise pavements:

Porosity, texture and stiffness are the three main physical properties of road surfaces that affect noise emission from road-tyre contact. Texture in particular will also influence to varying degrees other important characteristics such as skid-resistance and rolling resistance. As discussed below, all of these properties can be strongly influenced by the choice of aggregate used and it's grading (size distribution). A road surface is defined partly by the size range of aggregate used. For example SMA 0/16 represents a stone mastic asphalt surface with aggregates between 0 and 16 mm in size. A further detail is the type of grading within a particular aggregate size range. These can be either "dense graded", "gap-graded" or "open graded". The differences between these grades are illustrated below:

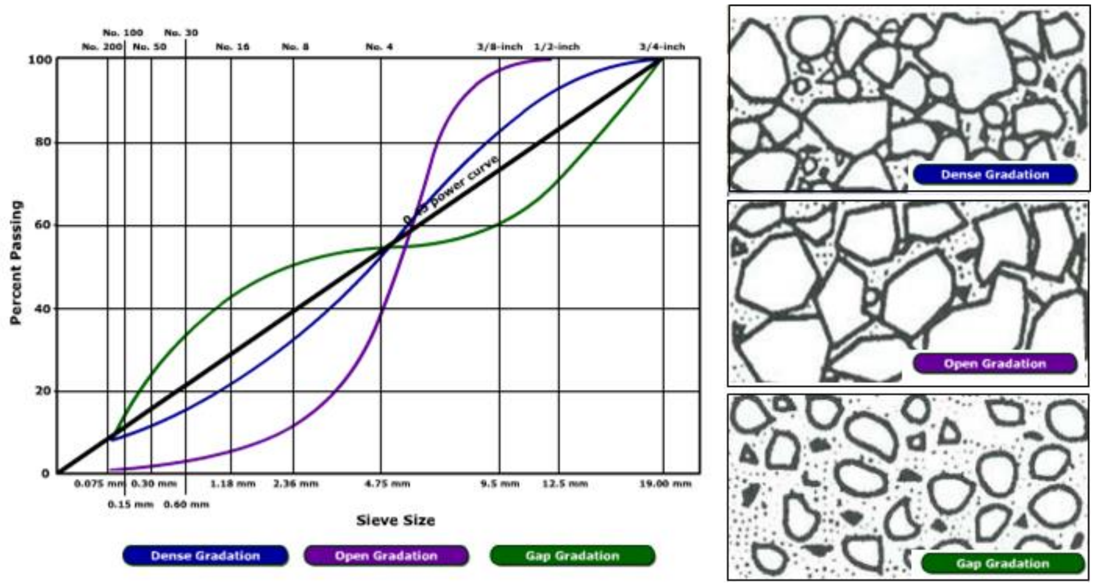


Figure A 14: Comparison of dense graded, gap-graded and open-graded aggregates (left – cumulative size distributions and right – normal distribution). Curve distributions from http://www.pavementinteractive.org/article/gradation-and-size/

From Figure A 14 it is clear that open graded aggregates are dominated by the coarse size aggregate fraction and only contain a very small portion of fine aggregates. Fine aggregates are important for filling the gaps between coarse aggregates and so their absence results in the creation of a relatively high proportion of open and interconnected voids (typical ≥20% volume). This is especially important in the drainage of the surface course and is useful for noise reduction properties.

Gap-graded aggregates contain significant contents of fine aggregates and course aggregates but very little or no aggregates of an intermediate size. This results in a moderate increase in the void content of the pavement surface (anywhere from 5-18% volume) but with a lower degree of interconnectivity.

Dense-graded aggregates contain the full range of aggregate sizes that are often spread in a normal Gaussian type distribution and result in the optimum packing of aggregates to form dense paving surfaces (*i.e.*, void content ≤5% volume).

Technical aspects - Generic types of low-noise road surface

(i) Porous road surfaces

Porous surfaces were originally developed in the 1970's and with the aim of improved road safety due to improved visibility, reduction of water spray and reduced risk of aquaplaning in wet conditions. The reduced noise emission was a secondary result. However, as noise emissions have become more of a concern, the use of porous pavements has gained significant interest during the last 25 years.

Porous surfaces can help reduce noise emissions by minimising the air pumping effect in tyre treads and also absorb some sound waves in the void network. In the Netherlands, the use of open-graded porous asphalt concrete 0/16 (PAC) has been reported to show SPB noise reductions of 3.5-4.0 dB, reducing to 2 dB after 8 years. By capping the porous layer with another porous layer with finer pores (using finer maximum aggregate size) to make double layer PAC (DPAC) the noise reduction performance can be improved to 5-6 dB initially and 3 dB after 8 years (Sandberg, 2009). Intensive research in the Netherlands into improving DPAC techniques is likely to improve these noise reduction performances further.

The drop in noise reduction performance of porous surfaces is widely linked to clogging of the voids in the pavement. DPAC can restrict the extent of clogging, or at least make cleaning operations more effective, by retaining grit and other solids in the finer upper porous layer, effectively restricting the ingress of solids further down the pavement profile and protecting the second porous layer. An example of double layer PAC and its composition is illustrated below:

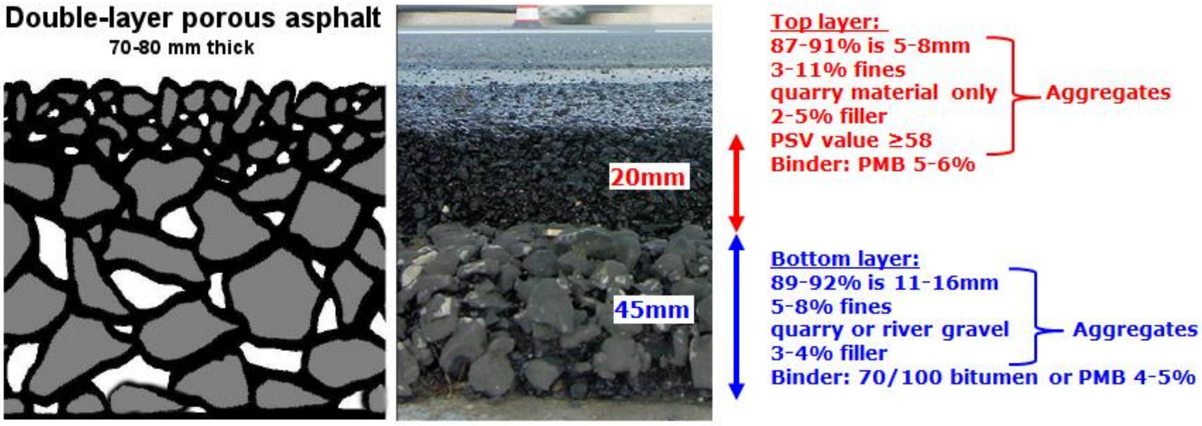


Figure A 15: Example of possible DPAC cross section and mix composition (Adapted from: Sandberg, 2009).

The use of porous asphalt has been widely introduced on high speed roads in the Netherlands and Italy but has been limited in Austria due to concerns with winter maintenance and shorter lifetimes compared to DAC (Haberl and Litzka , 2008). PAC and DPAC have significant differences to traditional asphalt courses and it is strongly recommended that if this option should be considered by the procurers, that the following factors also be taken into account:

- PAC or DPAC is not very suitable in road sections subjected to horizontal forces, in steep road sections, small roundabouts, crossroads and areas with frequent braking and acceleration and is prone to premature ravelling compared to more dense asphalts.
- Clogging is more of a problem in low speed roads due to the lack of self-cleaning action by tyres. Some allowance may be needed for the annual cleaning of hard shoulders in high speed roads. DPAC is easier in theory to clean than PAC because the solids should be caught closer to the surface.
- In dry climates, the lack of rain to flush the void network exacerbates the clogging of PAC or DPAC.
- Durability of PAC may be adversely affected by laying in cold weather (*i.e.*, below 15°C). With DPAC, it is preferable if the top layer can be laid in the same operation as the lower layer (specialised equipment necessary).
- DPAC offers better noise reduction performance than PAC but generally takes longer to lay and is more expensive. The cost of DPAC may be up to 100% more than traditional asphalt pavements.
- If retrofitting PAC onto existing roads, the drainage system may need to be modified – a potentially significant capital cost.
- It is possible that DPAC will present lower skid resistance during the first few weeks of operation if this is not considered in the mix design.
- Ice formation in clogged pores is a particular concern in cold climates, both due to safety and to the physically damaging effect of freeze-thaw cycles on the pavement structure.
- The noise reduction of PAC is not so good during rainy weather due to filling of the pores with water but also at least 4 hours after rain has fallen as the pores remain partly saturated. Consequently the benefits of noise reduction of porous pavements in rainy climates may be over-estimated if measurements are only taken in dry conditions and vice versa.

(ii) Thin overlays

In low speed road sections where the self-cleaning action of tyres is limited, concerns with ice formation exist and/or significant horizontal forces exist, one promising alternative to porous surfaces for low-noise pavements is thin overlays. Thin overlays are arbitrarily considered to have a maximum thickness of 30mm and can be quickly laid. Compared to traditional dense asphalt concrete (DAC), costs are reduced due to the lower volume of material required but this is offset by the need for high quality aggregate and higher binder contents. Overall, the costs of laying thin overlays in the city of Ede in the Netherlands was around 5% more than DAC and the lifetime reduced from 12 years to an expected 8-10 years with thin overlays. However, the thin overlays can provide initial noise reductions of 3-4 dB at 50kph and 6 dB at 70kph (Sandberg, 2009). Life-time costs are difficult to assess as it is still unclear how thin overlay durability compares to traditional pavements over long periods, but thin layers can generally be considered at least as durable as porous pavements.

According to the OPTHINAL report (2011) the use of thin overlays should be avoided in urban cross-roads and steep uphill road sections where vehicle tyres exert the highest shear forces. If climate conditions make the use of studded tyres likely, then good quality and larger maximum aggregate sizes (hence thicker layers) should be used. An additional consideration is that thin layers are not particularly well suited for the re-use of old asphalt pavement because high specification aggregates are required. However, the use of up to 30% reclaimed asphalt pavement (RAP) can be used in asphalt plants that are able to add milled material – although not all plants have this capability (Nicholls *et al.*, 2008).

(iii) Rubber containing surfaces

These types of surface can be split into two main categories: asphalt rubber (AR – also known as rubberised asphalt) and poro-elastic road surfaces (PERS). The principle difference can be considered that in AR, the rubber is used in the binder component (bitumen or asphalt cement) and in PERS the rubber is used in the aggregate component. Because aggregates represent the dominant component of asphalt concretes, much larger quantities of rubber can potentially be used in a given volume of PERS than AR.

Asphalt Rubber binders were pioneered in the 1960's in Arizona and are defined in ASTM D8 as "*a blend of asphalt cement, reclaimed tyre rubber and certain additives, in which the rubber component is at least 15% by weight of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles*".

These binders were originally developed to reduce the need for frequent maintenance due to problems such as rutting and cracking in traditional asphalt pavements. However, the noise reduction potential of AR was also notable. Apart from the rubber content, the other major difference between AR pavement and conventional asphalt pavement is that the binder content is 50-100% higher. Consequently the costs of AR are more sensitive to the price of bitumen than conventional asphalt.

The US approach to noise emission management almost exclusively focusses on noise barriers (noise walls). Due to concerns about their cost-effectiveness and long term durability, low-noise pavements are not funded by the Federal Highways Administration in the US and any possible benefits from low-noise pavements that are installed cannot be officially taken into account in any noise mitigation measures. The result is that AR pavements have so far only been trialled in Arizona and California to date because these states have specifically agreed to invest and partake in evaluation projects. Noise reductions of 2-10 dB in AR pavements were listed in a Sacramento County report (1999) but it was uncertain what these reductions were compared to and if these where just initial reductions only. According to SPB results presented by Kudrna and Dasek (2010), porous AR with air void content of 13-18% resulted in a noise decrease of 2.3 dB compared to a stone mastic asphalt 11 (SMA 11) course. Swedish data reported by Sandberg (2010) highlighted that noise reductions in AR pavements will be related both to the increased binder content and the rubber content. He estimated that the effective contribution of rubber alone to noise reduction was of the range 0.5-2.0 dB. The same work also illustrated that asphalt rubber does not present higher rolling resistance than similar non-rubber pavements but instead is strongly correlated with the macrotexture (mean profile depth measurements).

Certain technical factors have to be considered with AR in comparison to conventional asphalt. For example, inside the asphalt mixer, higher temperatures are required to ensure that viscosity increases due to the rubber content of the binder are minimised. According to the Arizona Department for Transport (ADOT) one major technical issue with the laying of asphalt rubber is that good adhesion to the base or binder course is only achieved when the ambient temperature is ≥29°C, this may be achievable for significant periods in Arizona or California but not in northern European countries. Nonetheless, it seems that modifications to the technique and mix can be made in order to use AR in colder climates such as Alberta, Canada (Treleaven, L., *et al.*, 2006) and Sweden (Sandberg , 2010). As with conventional asphalt binders, the development of more porous AR surfaces can be achieved by using gap-graded or open-graded aggregates that can enhance noise reduction properties. The noise reduction performance of AR compared to standard asphalt mixes was demonstrated in both countries although noise reductions appeared more stable during the first few years in

Sweden whereas a notable reduction was observed in the Canadian study. In any case, it is important that if AR pavement is to be specified or chosen, that the contractor is capable of complying with relevant technical specifications and has a good degree of experience with such mixtures and their deployment in that specific region, or at least in other regions with similar climatic conditions.

Poro-elastic road surfaces (PERS) are described by Goubert *et al.* (2014), as: "*…a wearing course for roads with a very high content of interconnecting voids so as to facilitate the passage of water and air through it, while at the same time the surface is elastic due to the use of rubber (or other elastic products) as a main aggregate. The design air void content is at least 20% by volume and the design rubber content is at least 20% by weight.".* Unlike AR, PERS do not use bitumen binders, instead using polyurethane or another elastic resin that may account for 5-17% of the total PERS weight. While AR has many properties similar to conventional asphalt, PERS is a completely different type of surface and is widely considered as the having the best potential for noise reduction (up to 12 dB).

Research into PERS has been undertaken since the 1970s (Sandberg, 2011) but the general conclusion is that although very promising noise reduction performance is observed, the surfaces generally fail prematurely under normal traffic conditions. Currently an EU research project (PERSUADE) is being undertaken with the aim to optimise the development of PERS mixes for satisfactory technical performance, durability and noise reduction. However, at this stage, caution would be urged when considering PERS as road surfaces in road construction tenders due to doubts about their long-term durability. Concerns over the possible increase in rolling resistance of the softer PERS are well founded but initial data seems to suggest that PERS can present surprising good (low) rolling resistance (Sandberg, 2013). Significant differences may exist between the optimum PERS system for lower rolling resistance of heavy vehicles and that of light vehicles.

One common consideration to both AR (lesser extent) and PERS (much greater extent) pavements is their ability to use recycled materials in the surface course, namely rubber from vehicle tyres, which are a problematic waste stream in many parts of the world.

(iv) Low-noise cement concrete road surfaces

The majority of R&D involving low-noise pavements has focussed on asphalt surface courses. However, the same physical principles that affect noise emission from tyre-road contact also apply to cement concrete, namely texture, porosity and stiffness.

Cement concrete surfaces are inherently stiffer than asphalt surfaces and this intrinsic property cannot be manipulated very much. Unlike asphalt, the surface texture of concrete is naturally very smooth and texture has to be created artificially, this provides an opportunity to carefully optimise the surface texture. This property can be manipulated in several ways in cement concrete pavements by specialised techniques as described in the SILVIA report (2006):

- Transverse, longitudinal or randomly ordered tining of the surface by creating grooves by dragging of specialised combs or burlap along the fresh concrete surface.
- Exposed aggregate surfaces created by brushing of recently hardened concrete where the surface layer remains fresh due to the application of a retarding agent. The brushing removes the mortar on the concrete surface, revealing the underlying aggregate on the new surface.
- Polishing of already hardened cement concrete road surfaces to create longitudinal grooves into the surface using diamond grinding techniques.
- The application of epoxy-bound surface treatments to concrete surfaces. A number of proprietary products have been developed for this purpose. These can reduce noise emissions from already existing cement concrete surfaces.

Particularly in the US, the widespread use of transverse tining due to concerns over the need for better friction on road surfaces has led to increased noise emissions due to the very regular and repeating nature of transverse grooves creating tonal spikes around 1000 Hertz, where human hearing is particularly sensitive. A comparison of different textured cement concrete road surface appearances is shown in Figure A 16.

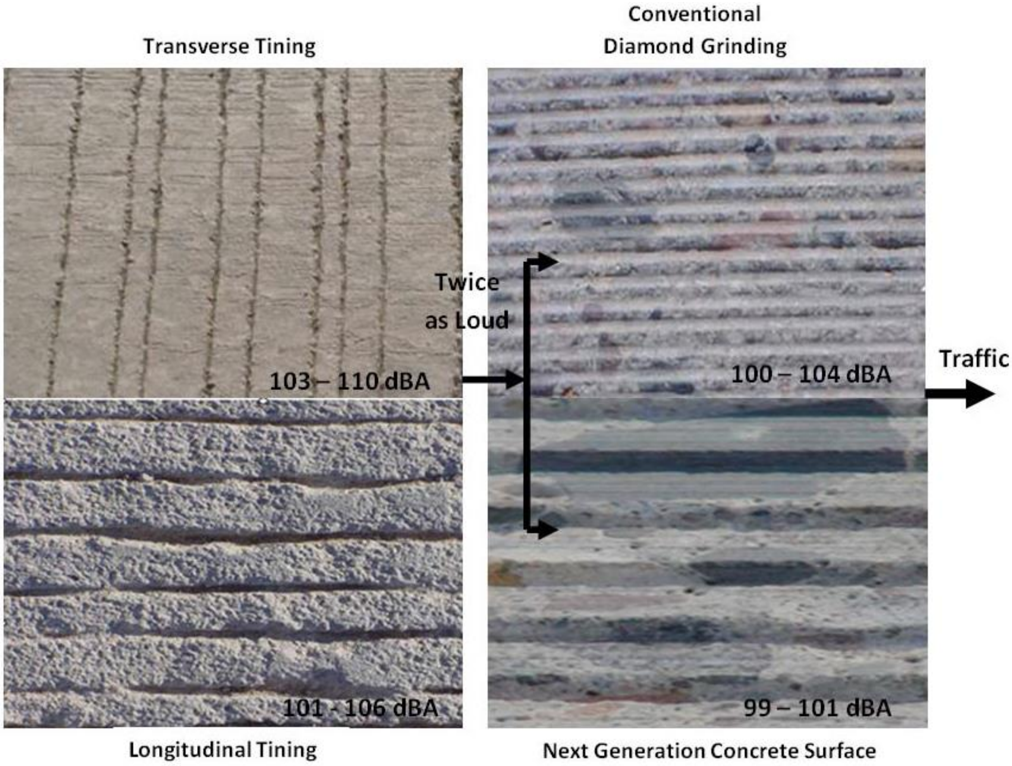


Figure A 16: Typical cement concrete surface textures and their typical OBSI noise levels (Scofield, 2009) Note that OBSI is the US equivalent of the CPX measurement technique.

Data comparing noise emissions from asphalt and cement concrete road surfaces in SILVIA seem to show that optimised concrete surfaces can present similar or even slightly improved noise reduction performance when compared to traditional standard asphalt courses and thin overlays but that cement concrete surfaces do not reach the noise reduction levels demonstrated by optimised asphalt courses(SILVIA, 2006).

At present, it appears that that the best performing asphalt pavements offer a better noise reduction performance but proponents of cement concrete road surfaces highlight the superior durability of noise reduction performance in cement concrete. Medium-long term studies that use well designed and unbiased approaches and that include cost data would be of great value in providing information to the procurer of the optimum life cycle costs for a particular level of noise emission reduction.

One interesting development that may prove to be the way for future high performance low-noise cement concrete roads is that of prefabricated slabs that have distinct layers incorporated into the slabs that include an optimised texture surface, an underlying porous layer and underneath, a dense concrete layer for load bearing.

Figure A 17: Example of a novel and multi-layer prefabricated cement concrete pavement for noise reduction (Sandberg, 2009).

The advantages or this system are good quality control under factory conditions, extremely flat and even surfaces due to casting in moulds and the potential for rapid laying of road surfaces. Noise reduction performance of around 6 dB was observed in a pilot study compared to conventional DAC (0/16). This is far superior to any traditional cement concrete pavement, even with optimised surface tining.

Technical aspects - Durability of low-noise pavements and maintenance requirements

In general it is easy to imagine that porous pavements are physically less durable than dense pavements due to the increased exposure of binder to oxidation and the irregular nature of surface areas in porous pavements. The need for maintenance in road pavements is traditionally triggered by physical wear, increases in roughness, potholes, joint repair and crack formation. However, in low-noise pavements maintenance programmes should ideally also consider the durability of the low-noise performance.

It is obvious that changes in road surface texture and clogging of voids will adversely affect the noise reduction achieved as the pavement ages. Whether a durability of noise reduction performance is required or not is something that should be clearly stated in the ITT. If noise reduction durability is specified it should be anticipated that it is possible that maintenance activities may be triggered due to loss of noise reduction before other maintenance is required.

Another two important points to consider are:

- How is noise reduction quantified at the beginning and during the lifetime of the pavement (*i.e.*, compared to what reference)?
- What methods are used to periodically assess noise emissions?

Regarding the first point, it can be appreciated that of most local relevance is a comparison of the old pavement with the new pavement. However, once the old pavement disappears, it can no longer be measured and comparisons can become biased for example if weather conditions change significantly when testing the new surface later on. If a reference surface is laid at the same time as the low-noise surface in the same site then this could be particularly useful for comparison but then is of limited value when comparing data from other countries that may use significantly different reference pavements. Even if the same reference surface is laid in different countries it will never give an identical reference value due to the potential subtle influences of aggregate source, paving technique, underlying base course and the machinery, operator skill and weather conditions when laying.

The EU-funded projects HARMONISE and IMAGINE looked at the development of a common reference system for comparing the noise reduction performance of pavements, including the potential of a "virtual reference pavement" that can be used to compare any road surface in any site. The use of such a system would greatly help procurers to compare different low-noise pavements objectively.

Sandberg (2009) discusses a series of virtual reference pavements (DAC or SMA with 0/8, 0/10, 0/11, 0/12, 0/14 or 0/16 aggregates) that represent the most commonly used "traditional" asphalt surfaces and how data can be normalised to allow for changes between DAC and SMA and between aggregate distribution ranges. Some correction factors to allow for reference pavement ageing up to 2 years are also provided but not beyond. Another potential factor that may be relevant is the meteorological conditions (temperature, humidity, rainfall *etc*.).

Selected data from the LEOPOLDO project (Licitra *et al.*, 2015a) that used noise data from several low-noise road surfaces in the Tuscany region highlights some of the potential differences that can occur depending on how noise reduction performance is assessed.

From the CPX data obtained in the Lucca site shown in Figure A 18 it can be highlighted that evaluating the noise reduction comparing tested surface results to those obtained for the old pavement measured in the past or for a reference pavement measured on the same day can be significantly different.

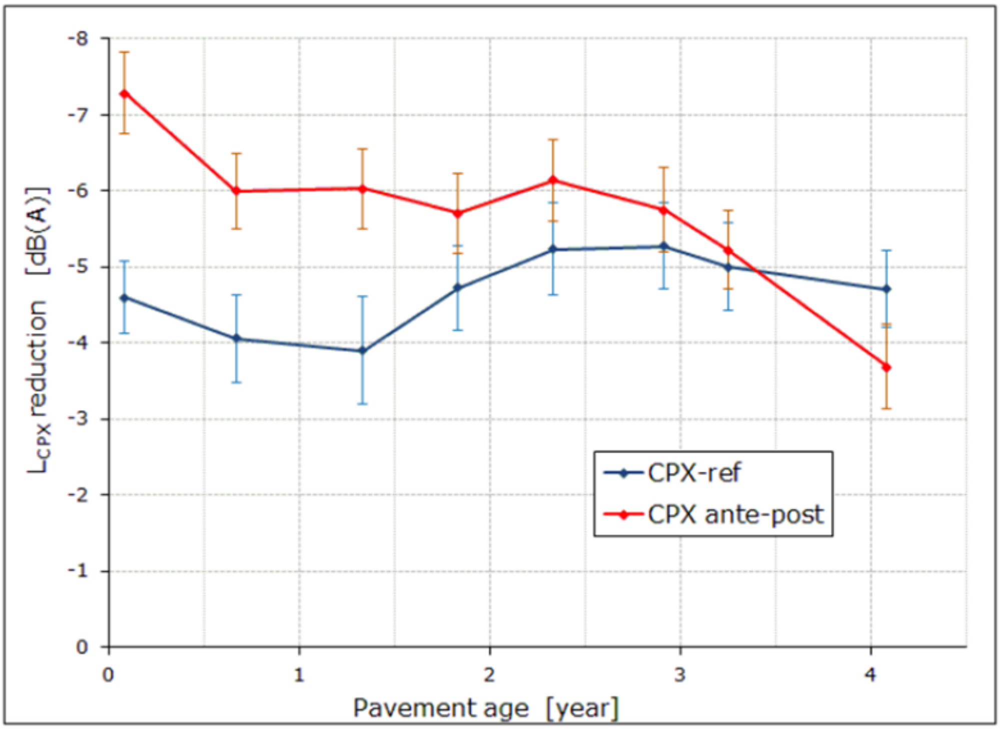


Figure A 18: Monitoring of noise reduction performance of a low-noise surface in Lucca by: CPX-ref (CPX measurements compared to a reference surface, taking measurements on the same days); CPX-ante-post (CPX measurements compared to one-off data from the previous surface) (Licitra *et al.*, 2015a).

From the Lucca data in Figure A 18, it can be concluded that there is a gradual decrease in noise reduction performance when comparing data to a one-off measurement from a previous pavement (ante-post) whereas the noise reduction performance appears much more stable and may even improve when comparing to a reference road surface measured on the same day and under similar conditions.

When comparing noise data from SPB and CPX tests, sometimes a good correlation may be observed and sometimes not, as is illustrated in Figure A 19 (good correlation) and Figure A 20.

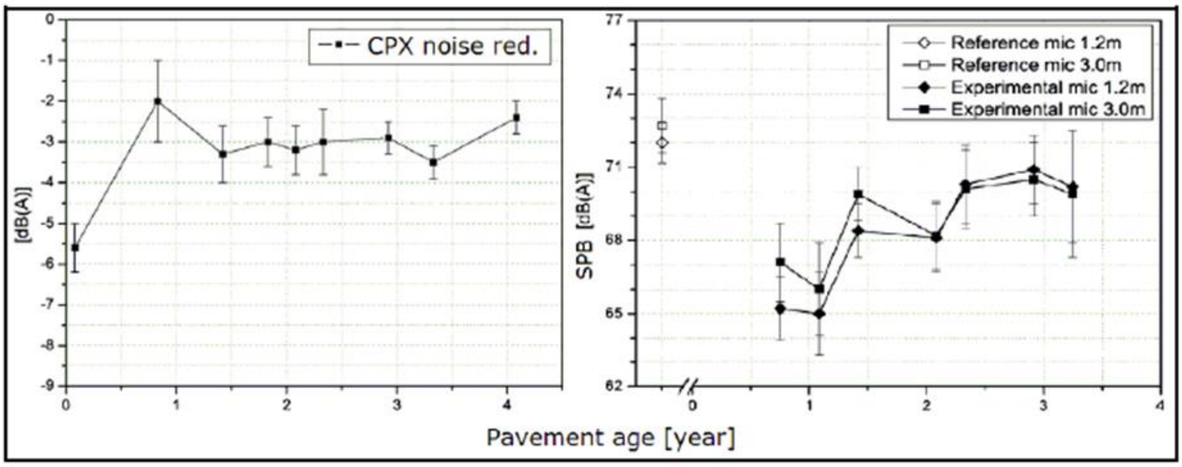
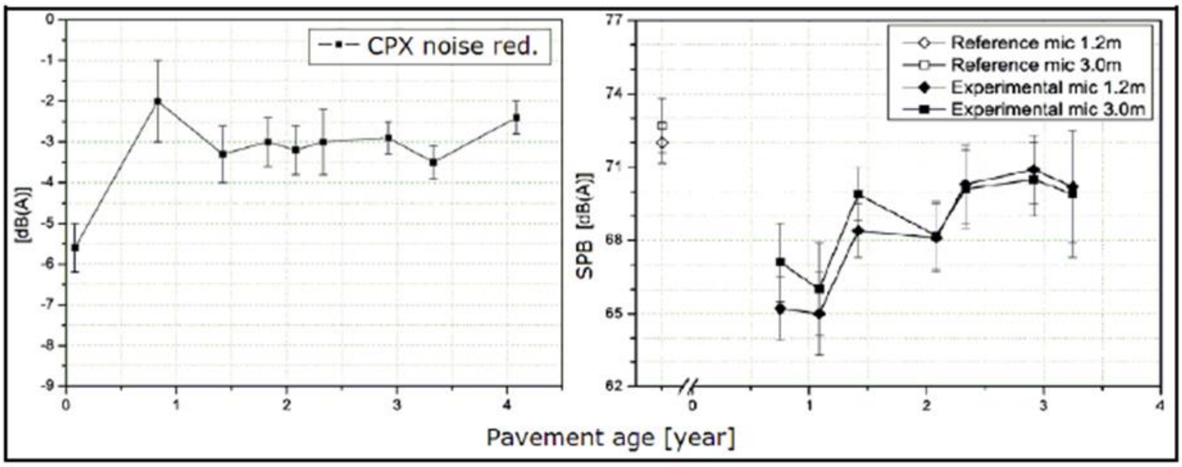


Figure A 20(poor correlation) **(Licitra *et al.*, 2015a)**.



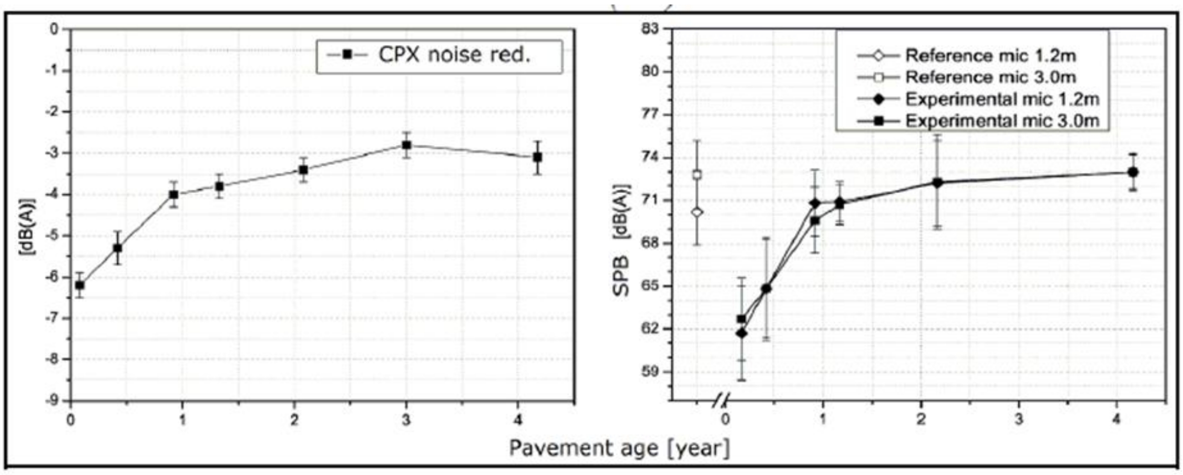


Figure A 19: Monitoring of noise reduction performance of a low-noise surface in Pisa by: CPX noise red. (CPX measurements compared to a reference surface, taking measurements on the same day); SPB (SPB measurements taken at 1.2m or 3.0m compared to one-off data for the previous surface) **(Licitra *et al.*, 2015a)**..

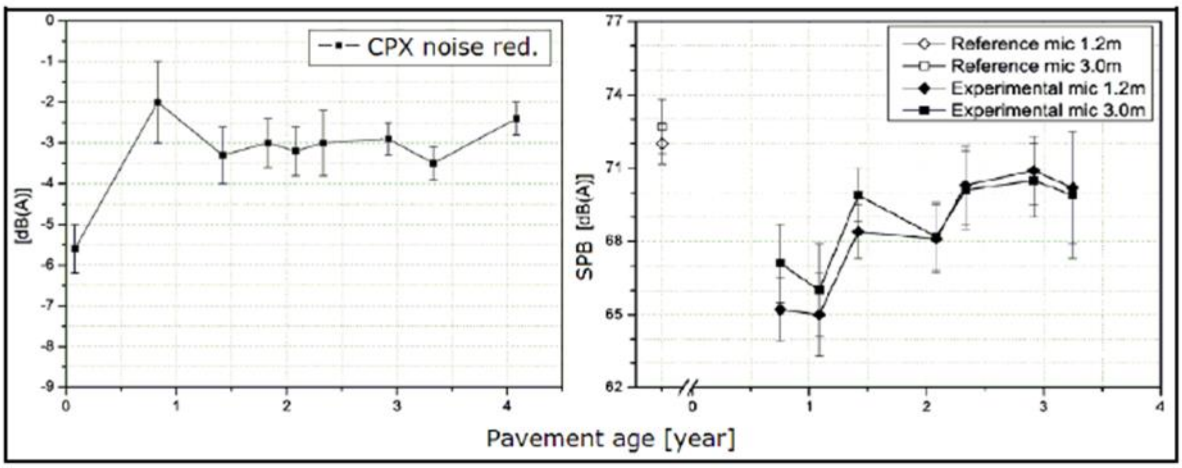


Figure A 20: Monitoring of noise reduction performance of a low-noise surface in Firenze by: CPX noise red. (CPX measurements compared to a reference surface, taking measurements on the same day); SPB (SPB measurements taken at 1.2m or 3.0m compared to one-off data for the previous surface). **(Licitra *et al.*, 2015a)**.

In general, since SPB data is point data, it is more susceptible to negative results if a relatively rare surface defect were to develop near the point of measurement during ageing. So for durability of performance monitoring, CPX data would be preferred to SPB data since this covers a much larger (and more representative) section of the road.

Annex 7 - Additional background technical aspects on LCC

Table A. 2: Comparison of annual infrastructure costs by selected studies (Doll and van Hessen, 2008 IMPACT D2).

Source	Country	Price basis	Network	Total costs million €	Unit costs 1,000 €/road-km	Heavy traffic share
ProgTrans/ IWW, 2007	DE	2005	All federal roads	18,190	342	38%
			Motorways	9,530	781	46%
			Fed. trunk roads	8,660	211	29%
BFS, 2007	CH	2005	All roads	4,970	70	15%
			National roads	1,974	1,124	n.a.
			Canton roads	1,339	74	n.a.
			Urban roads	1,055	21	n.a.
Herry, 2002	AT	2004	ASFINAG network	1,469	745	57%
CE, 2004	NL [1)]	2002	All roads	9,219	73	29%
			Rural roads	4,711	71	n.a.
			Urban roads	4,508	75	n.a.
UNITE D5	DE	2005	All roads	27,293	59	38%
			Motorways	5,100	418	57%
			Fed. trunk roads	4,566	111	35%
			Local streets	17,627	43	33%
	CH	2005	All roads	6,136	86	15%
UNITE D8	AT	2005	All roads	5,273	50	49%
			Motorways	1,222	601	60%
			Trunk roads	1,080	33	45%
			Local streets	2,970	42	46%
	DK	2005	All roads	1,345	19	n.a.
	ES	2005	All roads	9,479	57	n.a.
	FR	1998	All inter-urban roads	25,290	26	40%
			Motorways	6,709	721	40%
			Trunk roads	4,369	164	63%
			Local streets	14,446	16	35%
	NL	1998	All roads	4,895	39	n.a.
	UK	2005	All roads	13,836	37	n.a.
			Inter-urban roads	5,095	329	n.a.
UNITE D12	BE	2005	All roads	1,894	13	n.a.
	FI	2005	All roads	1,109	11	n.a.
	GR	2005	All roads	4,658	41	n.a.
	HU	2005	All roads	10,276	64	n.a.
	IT	1998	All roads	15,199	23	n.a.
			Motorways	3,778	622	n.a.
			Trunk roads	8,967	54	n.a.
			Local streets	2,453	5	n.a.
	LU	1998	All roads	146	8	n.a.
	PT	2005	All roads	0	0	42%
	SE	1998	All roads	2,411	17	n.a.
			Motorways	2,820	1,837	n.a.
			Trunk roads	1,123	11	n.a.

1) Without land take; network lengths from Table 8.

Collection of cost data for road construction and maintenance of highways and motorways according to OECD (2005)

Typical pavement structures

Table A. 3: Typical pavement structures (OECD, 2005).

Country	Typical structure HMA = Hot mix asphalt SMA = stone mastic asphalt CBC=crushed based course SB = sub-base	Wearing course thickness (mm)	Total asphalt thickness (mm)	Granular thickness (mm)	Total thickness (mm)	% asphalt of total structure	Structural equivalency (CGE)*
Canada	230 mm HMA , 150 mm CBC, 300 mm SB, silt	50	230	450	680	34%	910
Denmark	20 mm SMA, 60 mm HMA binder, 180 mm HMA base	20	260	600	860	30%	1120
	50 mm asphalt, 200 mm HMA , 450 mm CBC	50	200	450	650	31%	850
	150 mm HMA , 300 mm CBC,300 mm SB, silt	50	150	600	750	20%	900
Finland	40 mm SMA, thick granular	40	200	2000	2200	9%	2400
France	25mm+40mm+80mm asphalt, 270 mm+200 mm HB	25	145	470	615	24%	760
Hungary	50 mm SMA, 160 mm HMA , 300 mm CBC	40	200	300	500	40%	700
Netherlands	50 mm porous asphalt, 350 mm HMA , 1 m sand	50	400	1000	1400	29%	1800
Norway	35 mm SMA, 185 mm HMA , 700 mm CBC	35	220	700	920	24%	1140
Poland	40 mm SMA, 90 mm HMA , 140 mm CBC,200 mm SB	40	130	340	470	28%	600
Portugal	40 mm SMA, 230 mm HMA , 350 mm granular	40	270	350	620	44%	890
Sweden	40 mm SMA, 200 mm HMA , 1 m granular	40	240	1000	1240	19%	1480
UK	30 mm SMA on HMA on granular	30	310	180	490	63%	800
	30 mm SMA on HMA on cement	30	390	150	540	72%	930
	30 mm SMA on thick HMA	30	450	150	600	75%	1050
USA	Concrete 320 mm , 1200 mm base		320	1200	1520	21%	1840
*Structural equivalency is equal to two times the asphalt thickness plus the granular thickness (approximation)							

Existing pavement design and failure criteria

Table A. 4: Existing pavement design and failure criteria (OECD, 2005).

Country	AADT (k)	ESALs (millions)	%heavy trucks	Design method	Expected life (yrs) wearing course	Failure IRI	Criteria Ruts (mm)	Distress Cracking (%)	Are road user costs considered?	Comments
Canada	32	20	22	Personal method	15	2.2	15		No	HMA 2750 MPa
										CBC 200 MPa
										SB 100 MPa
				AASHTO						SG 20-75 MPa
Denmark	60	5	8	Danish standards	14	3.5	15		No	Skid resistance spec 0.5
										Stiffness modulus for HMA 3KMpa
Finland	17-45		15	Tables	5		13		No	Studded tire use
France	25		19	National standards	8-16		15-20		Yes	Expected life, 8 yrs for truck lane only
Hungary	20	18	10	National standards	7	3.2	14	25	No	
Netherlands	55	36	17	Netherlands method	9	2.5	18	20	Yes	Horizontal tensile strain 125 ms
										Skid resistance spec 0.44 SFC
Norway	22	3	15	Norwegian	5	4	25		no	Studded tire use
Poland	20	14	20	Catalogue	10	4.4	20	20	Yes	Horizontal tensile strain 125 ms, vertical 275 ms
										Static creep modulus > 14 MPa
Portugal	11	19	15	Shell method	15	3.5	15		yes	Skid resistance spec 0.4
Sweden	13	25	10	ATB (Swedish)	13	2.5	17	10	Yes	Skid resistance spec 0.5
UK	111	106	15	TRL report LR 1132	9	RQI	20	3	Yes	By policy, no new concrete
										Fatigue formulas are used, skid spec 0.35 SFC
USA	29	13	14	Fla DOT	30	2.4			No	Concrete Florida
	10	10	15	Mn DOT	18		13		No	Minnesota
	129	12	11	AASHTO	10	2.2	14	15	Yes	Colorado

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