Effects on Availability of Road Network (EARN)

Recycling: Road construction in a post-fossil fuel society

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CEDR
Conférence Européenne des Directeurs des Routes
Conference of European Directors of Roads

CEDR Transnational Road Research Programme Call 2012

Presentation 4: Modelling for EARN

Matthew Wayman
Senior Consultant, TRL Limited, UK

Overview

1. Objectives
2. EARN’s potential advantages
3. Modelling approach
4. Data collection & other parameters
5. Results & conclusions
6. Decision tree

WP4: Objectives

- Objectives
  - – Model how inclusion of reclaimed asphalt in road pavement materials affects performance in environmental and economic terms
  - – Select an appropriate modelling approach to allow impacts of recycling (positive or negative) to be quantified
    - Environmental impact: carbon
    - Economic impact: costs as net present value (NPV)
  - – Utilise a life cycle based approach
    - To evaluate ‘trade-offs’ in the life cycle
  - – Compile a decision tree to indicate a ‘hierarchy of considerations for asphalt recycling’

EARN: a unique opportunity

- Context
  - The asphalt industry was by no means ‘making a standing start’ with regards to asphalt recycling
    - EARN provided the opportunity to trial double-digit rather than single-digit recycling rates
  - Another sustainability initiative is lower-temperature asphalt
    - Can lower-temperature asphalt and recycling be combined?
    - Can one initiative successfully compliment the other?
  - A unique opportunity
    - EARN provided the opportunity to follow the asphalt production process from start to finish (raw materials to installation)
    - Mixture production could be witnessed first hand and energy consumption directly recorded using meters installed specifically for the trial
    - Having Lagan as a partner made this possible

EARN: a unique opportunity

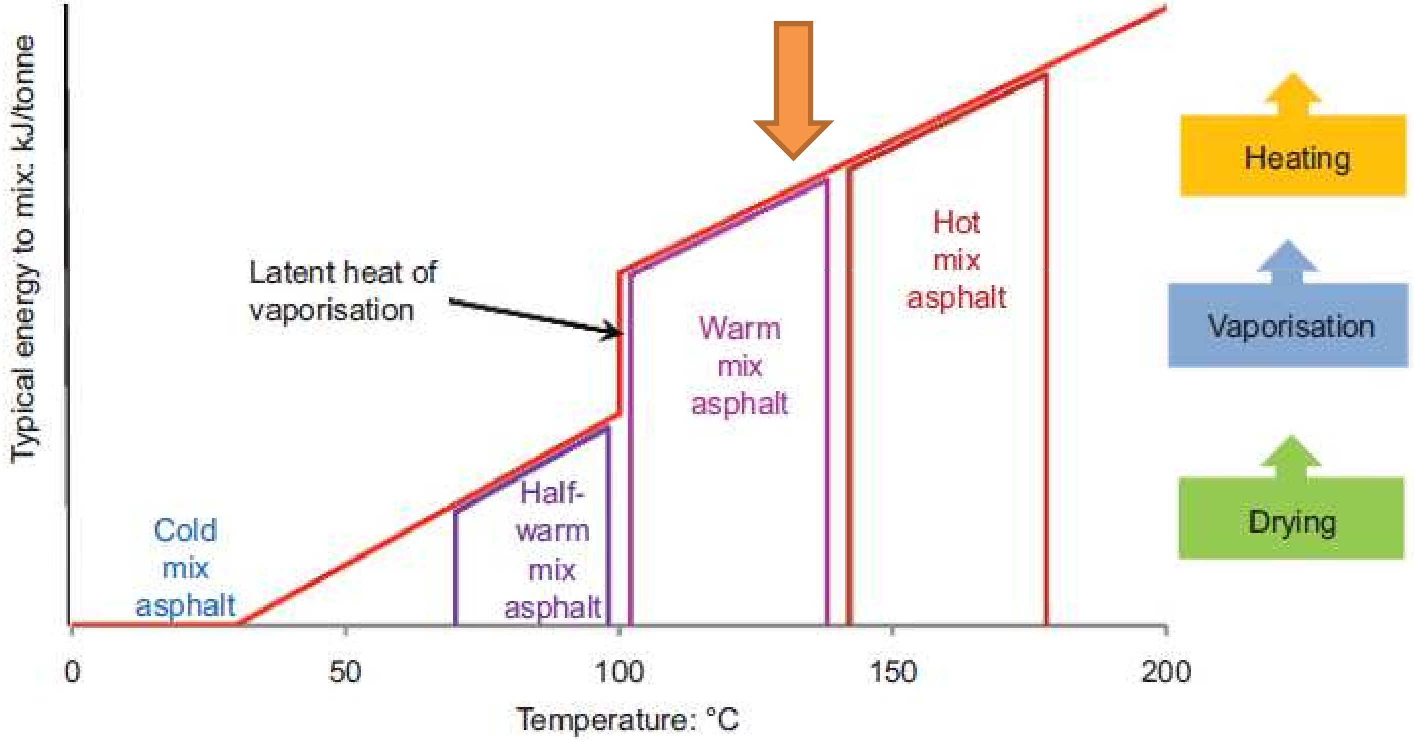
- Characteristics of recycling
  - Improved resource efficiency
    - Closed-loop recycling avoids the use of primary resources
    - The valuable properties of aggregates and bitumen are preserved into the next life
  - Lower ‘embodied’ impacts
    - Upstream impacts ‘cradle-to-gate’ are usually lower for recycled materials than those manufactured from virgin resources
  - Plant requirements
    - There is a need to compensate for a cold RA feed through:
      - *Superheating*
      - *A separate dryer (requiring capital outlay)*
      - *Another appropriate technology to compensate for moisture*

➢ A surfactant additive (CECABASE™ RT 945) was selected to compensate for moisture in the RA

- This also facilitated lower-temperature mixing at ~140 °C

EARN: a unique opportunity

- Lower-temperature asphalt



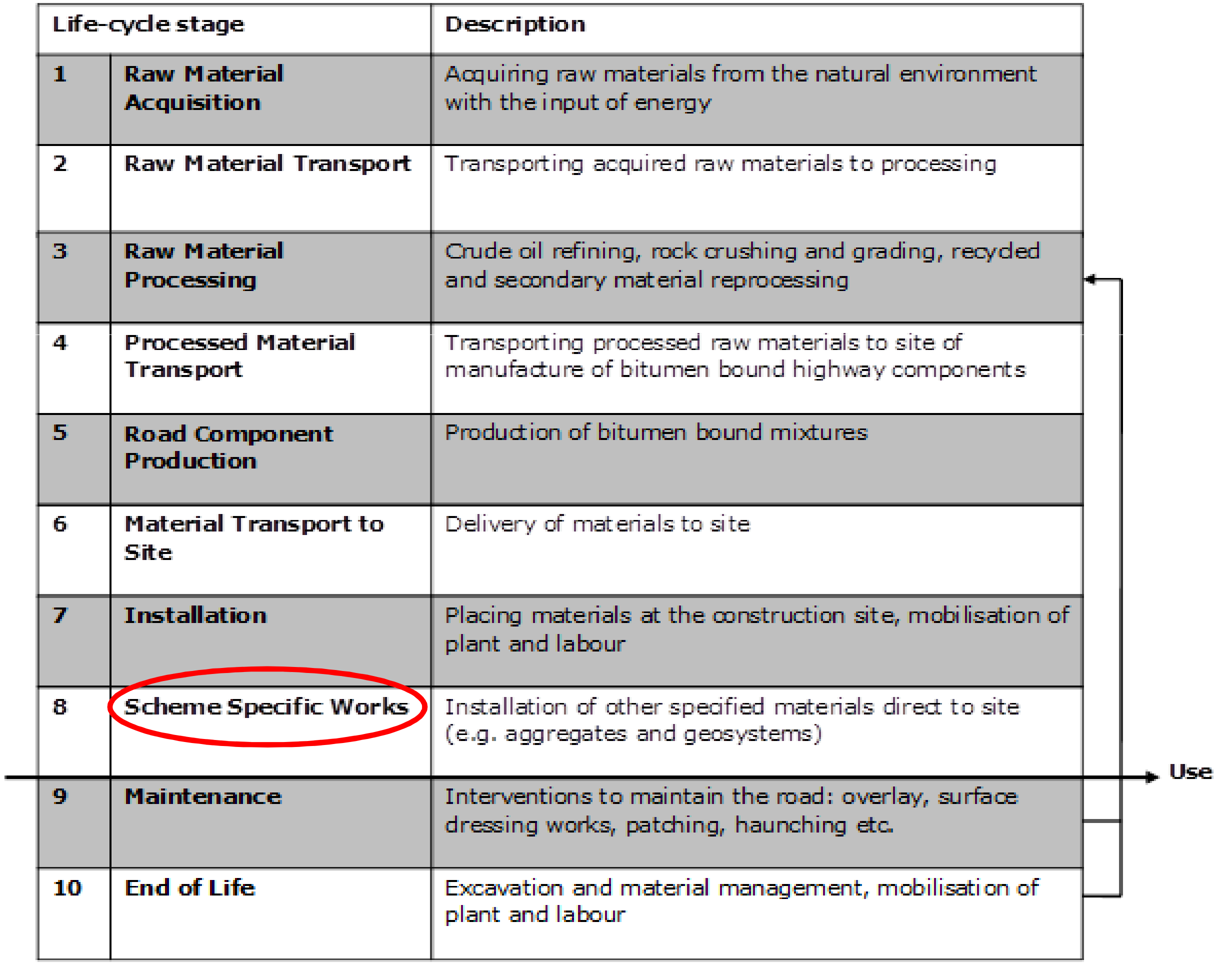
(Nicholls & James (2011) Literature review of lower temperature asphalt systems. *Proceedings of the Institution of Civil Engineers – Construction Materials. London: Thomas Telford*)

Modelling approach

- asPECT (the asphalt Pavement Embodied Carbon Tool)
  - Selected to model environmental impacts (CO_2e)
  - Why?
    - Facilitates a life cycle approach
    - The ability to analyse the CO_2e contributions of asphalt mixtures according to specific mixture recipes
    - Accepts specific plant energy consumptions
    - Specific national emissions factors
    - Specific pavement lifetimes for different nations
- A bespoke method was developed to evaluate life cycle costs
  - Using actual costs of components, energy, haulage and estimates of labour
  - A 60 year investigation period
  - A calculation of Net Present Value (NPV) to allow future costs to be compared today (UK Treasury Green Book)
    - Start to year 30: 3.5 % discount rate
    - Year 31 to 60: 3.0 % discount rate

Modelling approach

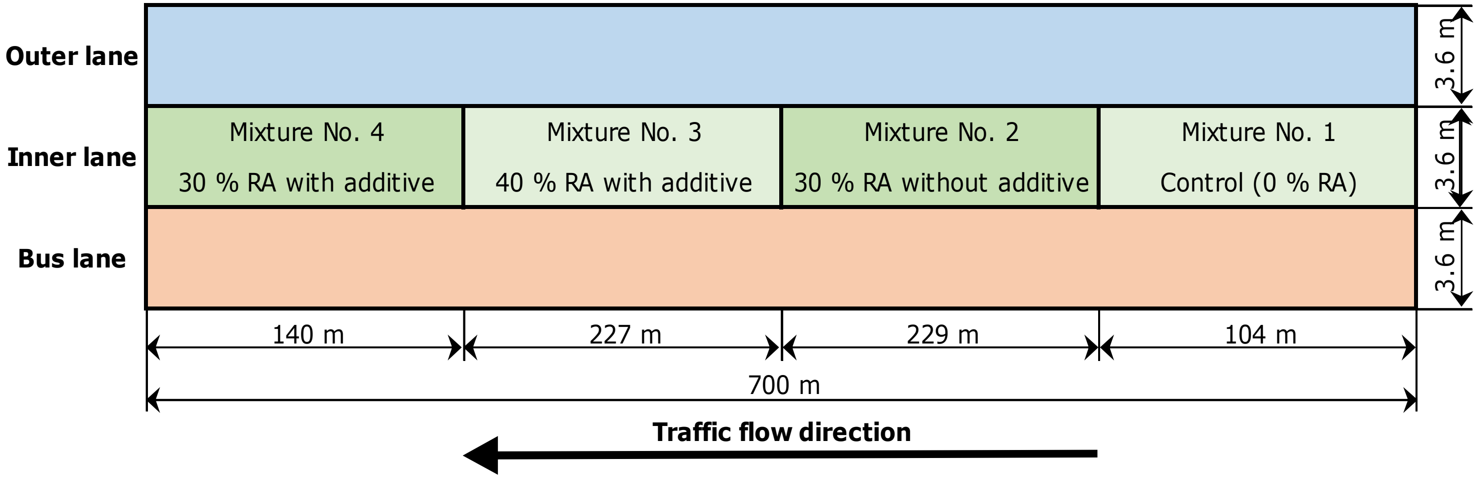
- The asphalt life cycle



Life-cycle stage		Description
1	**Raw Material Acquisition**	Acquiring raw materials from the natural environment with the input of energy
2	**Raw Material Transport**	Transporting acquired raw materials to processing
3	**Raw Material Processing**	Crude oil refining, rock crushing and grading, recycled and secondary material reprocessing
4	**Processed Material Transport**	Transporting processed raw materials to site of manufacture of bitumen bound highway components
5	**Road Component Production**	Production of bitumen bound mixtures
6	**Material Transport to Site**	Delivery of materials to site
7	**Installation**	Placing materials at the construction site, mobilisation of plant and labour
8	**Scheme Specific Works**	Installation of other specified materials direct to site (e.g. aggregates and geosystems)
9	**Maintenance**	Interventions to maintain the road: overlay, surface dressing works, patching, haunching etc.
10	**End of Life**	Excavation and material management, mobilisation of plant and labour

Data collection

- The installed sections on the N3



Outer lane				
Inner lane	Mixture No. 4 30 % RA with additive	Mixture No. 3 40 % RA with additive	Mixture No. 2 30 % RA without additive	Mixture No. 1 Control (0 % RA)
Bus lane				
	140 m	227 m	229 m	104 m

Traffic flow direction

Data collection

- Collated information:
  - Plant batching records
  - Mixture recipes
  - Metered energy consumption (gas oil and electricity)
  - Laying records
  - Cost data for mixture components, haulage and energy

Data collection

- Cradle-to-gate constituents and costs:

Constituent	kgCO$_2$e/t	Cost €/t
Aggregates	4.4	16.75
Crushed rock fines	4.4	16.75
RA planings	0.31	11.00
Imported filler	4.4	20.00
Polymer-modified bitumen	370	730.87
CECABASE™ additive	2,100	5,583.20

Data collection

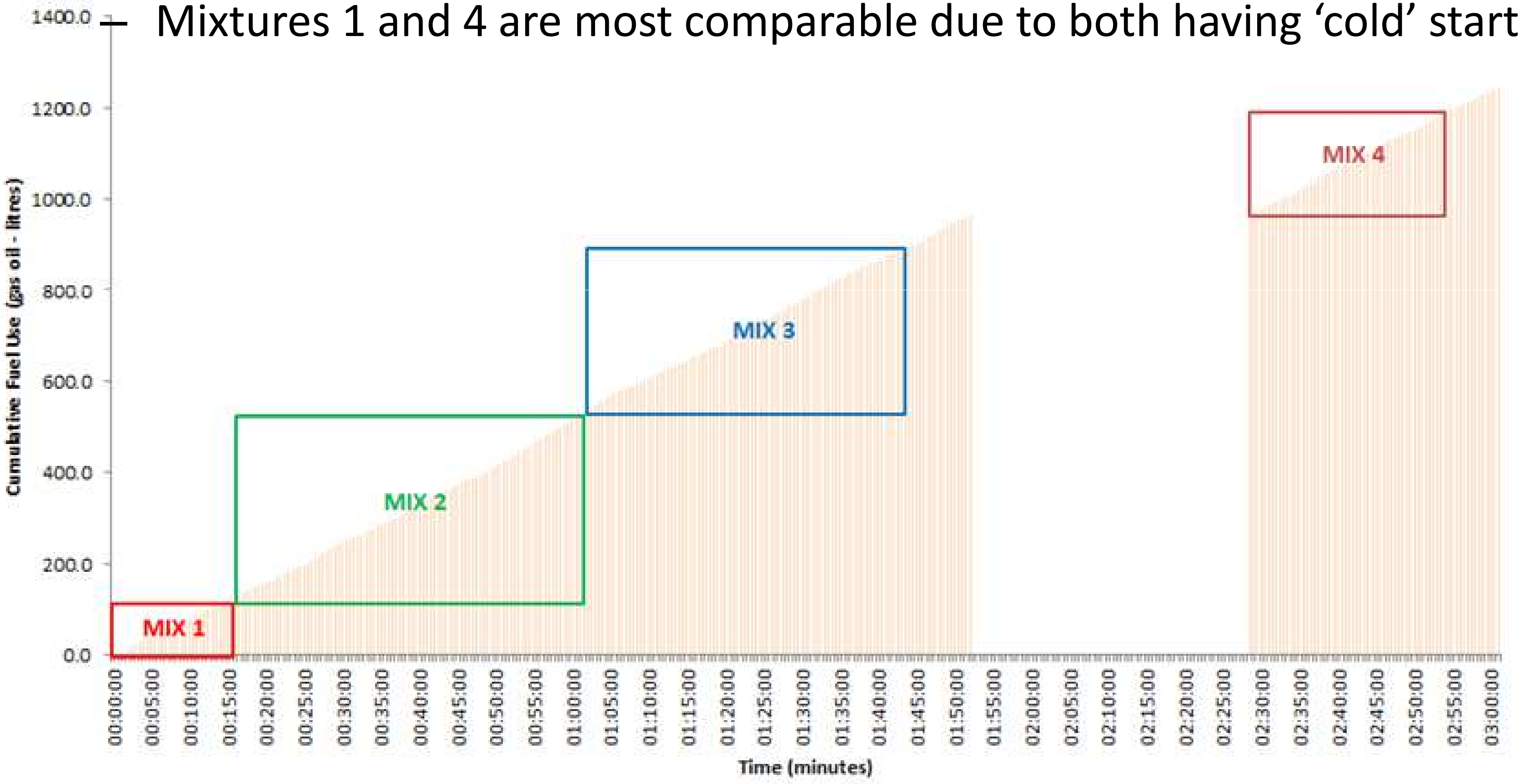
- Mixture recipes

Component	Mixture 1 – SMA 0% RA control	Mixture 2 – SMA 30% RA	Mixture 3 – 40% RA + additive	Mixture 4 – 30% RA + additive
Aggregates 10 mm (%)	65.06	43.68	34.40	43.89
Crushed rock fines (%)	22.31	17.08	16.99	16.95
RA planings (%)	0.00	28.51	38.20	28.55
Filler (%)	7.05	5.83	5.67	5.69
Polymer-modified bitumen (%)	5.57	4.90	4.71	4.90
CECABASE™ additive (%)	0.00	0.00	0.03	0.03
TOTAL	100.00%	100.00%	100.00%	100.00%

Material sources

Data collection – asphalt production

- Cumulative energy consumption at plant (gas oil)
  - Mixtures 1 and 4 are most comparable due to both having ‘cold’ starts



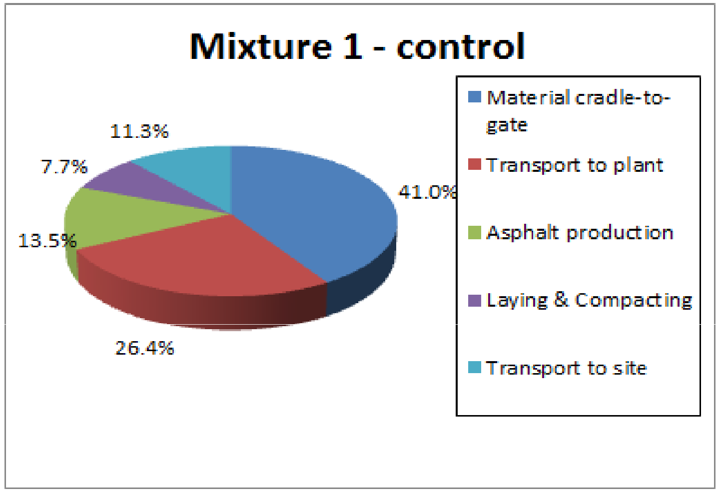
Results

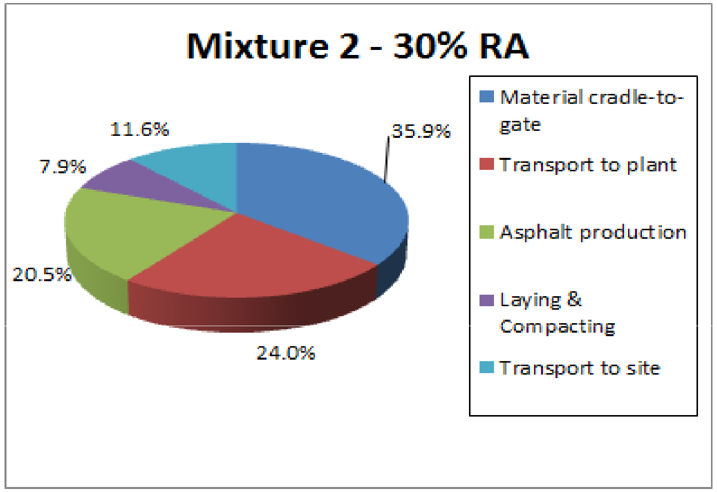
- Carbon footprint
  - Mixture-related

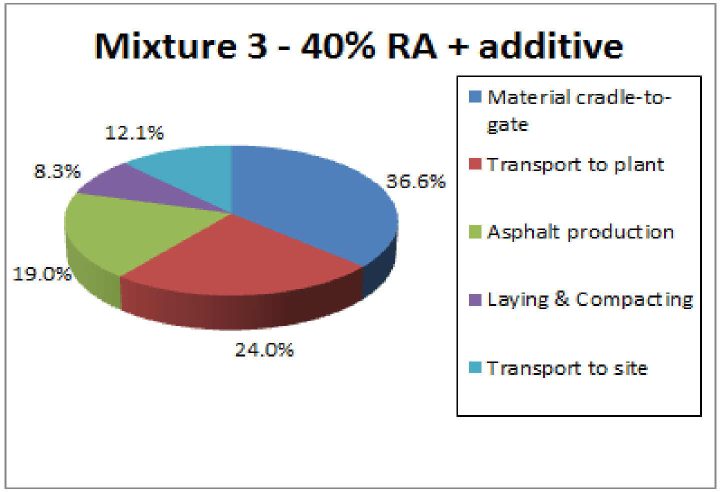
Component	Mixture 1 (SMA 0 % RA control)	Mixture 2 (SMA 30 % RA)		Mixture 3 (SMA 40 % RA + additive)		Mixture 4 (SMA 30 % RA + additive)	
Cradle-to-gate CO_2e footprint ($kgCO_2e/t$)	49,25	47,64	-3.3 %	45,20	-8.2 %	43,97	-10.7 %
Cradle-to-site CO_2e footprint ($kgCO_2e/t$)	60,83	59,22	-2.6 %	56,78	-6.7 %	55,54	-8.7 %
Total for the EARN trial installation ($kgCO_2e$) including regulating course and tack coat	18 784						

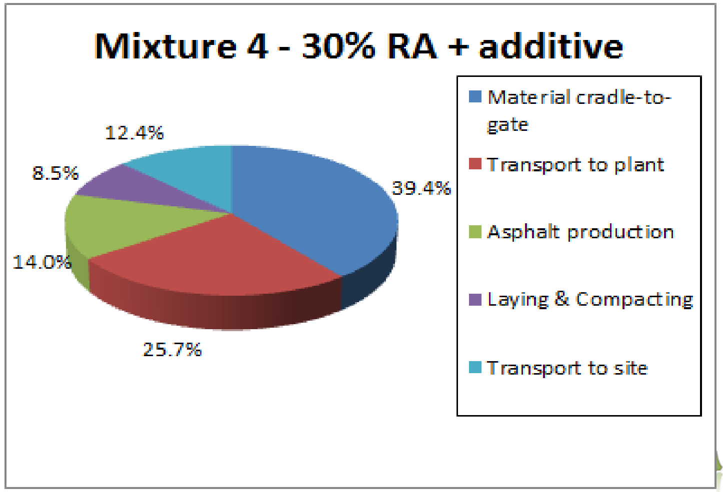
Results

- Carbon footprint breakdown cradle-to-site









Data collection

- Design lives (from Deliverable 3)
  - Shown to be quite variable – but the effect of this can be evaluated

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 course	SMA	16	22	11	17	8	–

Results

- Calculated CO_2e footprints for a 1 km single lane stretch over 60 years (absolute figures)

Cradle-to-grave CO_2e footprint for 1 km over 60 years ($kgCO_2e$), including tack coat	Mixture 1 (SMA 0 % RA control)	Mixture 2 (SMA 30 % RA)		Mixture 3 (SMA 40 % RA + additive)		Mixture 4 (SMA 30 % RA + additive)	
UK (8 year service life)	161 493	155 025	-4.0 %	148 942	-7.8 %	145 927	-9.7 %
Netherlands (11 year service life)	117 118	112 413		107 990		105 794	
Germany (16 year service life)	80 139	76 903		73 863		72 351	

Results

- Costs
  - Mixture-related

Component	Mixture 1 (SMA 0 % RA control)	Mixture 2 (SMA 30 % RA)		Mixture 3 (SMA 40 % RA + additive)		Mixture 4 (SMA 30 % RA + additive)	
Cradle-to-gate CO_2e footprint ($kgCO_2e/t$)	66,93	58,63	-12.4 %	57,01	-14.8 %	59,45	-11.2 %
Cradle-to-site CO_2e footprint ($kgCO_2e/t$)	114,66	106,36	-7.2 %	104,74	-8.7 %	107,18	-6.5 %
Total for the EARN trial installation ($kgCO_2e$) including regulating course and tack coat	72 482						

Results

- Calculated costs for a 1 km single lane stretch over 60 years
  - With a longer service life, costs are lower overall

Cradle-to-grave direct costs for 1 km over 60 years (€), including tack coat	Mixture 1 (SMA 0 % RA control)	Mixture 2 (SMA 30 % RA)		Mixture 3 (SMA 40 % RA + additive)		Mixture 4 (SMA 30 % RA + additive)	
UK (8 year service life)	-393 804	-378 062	-4.0 %	-375 989	-4.5 %	-379 120	-3.7 %
Netherlands (11 year service life)	-258 616	-247 833	-4.2 %	-246 413	-4.7 %	-248 557	-3.9 %
Germany (16 year service life)	-207 451	-198 545	-4.3 %	-197 373	-4.9 %	-199 144	-4.0 %

Results

- Indirect (user) costs for a 1 km single lane stretch over 60 years
  - Is it possible to re-open the road earlier using an LTA?
  - Interventions with HMA are modelled to last eight hours and those with LTA seven hours
  - Cumulative cost associated with this difference in working window over a 60 year asset life

Indirect costs for 1 km over 60 years (€), including tack coat	HMA	LTA	
UK (8 year service life)	-40 377	-35 330	-12.5 %
Netherlands (11 year service life)	-30 993	-27 119	
Germany (16 year service life)	-22 896	-20 034	

Results summary

- Clear savings are observed for the novel mix designs (Mixtures 2, 3 and 4) relative to the HMA control mixture (Mixture 1) in terms of both CO_2e and cost
  - CO_2e savings range from between 3,3 % to 10,7 % cradle-to-gate and 2,6 % to 8,7 % cradle-to-site on a per tonne basis
  - Mixtures 1 (control) and 4 (30% recycling with additive) provide the most equitable basis for comparison between a hot and lower-temperature mixture containing RA
  - Comparing Mixtures 1 and 4, the savings associated with using the hot mix would be 10,7 % cradle-to-gate and 8,7 % cradle-to-site
  - The cost savings associated with the lower-temperature, high recycled content mixture would be 11,2 % cradle-to-gate and 6,5 % cradle-to-site

Further analysis

- Some further scenarios were explored:
  - Huge differences were observed for anticipated design lives for the same type of asphalt in different countries
  - SMA surface course in the Netherlands is anticipated to last 37,5 % longer than in the UK and 100 % longer in Germany
  - A 37,5 % more durable pavement equates to a saving of 40 tonnes of CO_2e and €131k for the best performing asphalt material over a 1 km section
  - This far exceeds the savings by switching from HMA to LTA with high recycled content

Further analysis

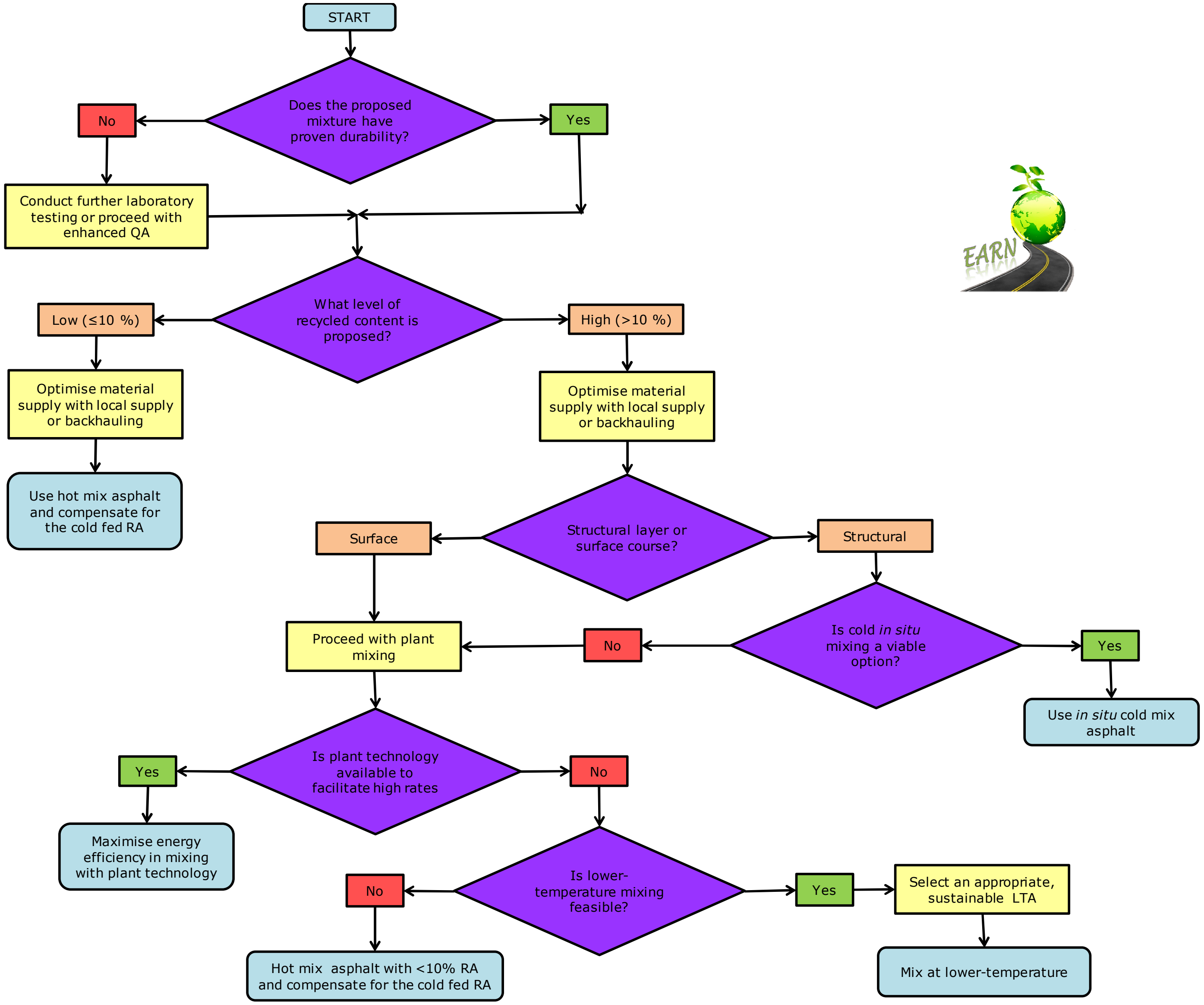
- The effect of backhauling
  - Utilise RA planings directly from the site being remediated (reverse logistics)
  - Trucks used to backhaul planings that can replenish stocks of RA at the asphalt plant
  - Can give up to a further 10,7 % CO_2e savings

Component	**Mixture 1 (SMA 0 % RA control)**	**Mixture 2 (SMA 30 % RA)**	**Mixture 3 (SMA 40 % RA + additive)**	**Mixture 4 (SMA 30 % RA + additive)**
Cradle-to-site CO_2e footprint - original (kgCO_2e/t)	60.83	59.22	56.78	55.54
Cradle-to-site CO_2e footprint – backhauling (kgCO_2e/t)	58.00	53.97	50.70	50.29
Saving %	-4.7 %	-8.9 %	-10.7 %	-9.5 %

Conclusions

- In general, appreciable CO_2e and cost savings can be observed for the novel asphalt mixtures relative to the control
  - CO_2e savings derived primarily from the recycled content that was incorporated (the primary aim of EARN)
  - Secondary savings derived from energy savings at the plant (through the lower heating and drying energy of the LTA mixtures)
- Recycling asphalt comes with a number of conditions:
  - Durability. Novel mixtures incorporating recycled content must perform to the same or an enhanced level when compared to the conventional hot-mix alternatives because reduced durability has the potential to make a huge negative impact in cost and environmental terms
  - Adequate consideration must also be given to logistics and minimising transport in the life cycle

Hierarchy of considerations for asphalt recycling



START

Does the proposed mixture have proven durability?

No

Conduct further laboratory testing or proceed with enhanced QA

Yes

What level of recycled content is proposed?

Low (≤10 %)

Optimise material supply with local supply or backhauling

Use hot mix asphalt and compensate for the cold fed RA

High (>10 %)

Optimise material supply with local supply or backhauling

Structural layer or surface course?

Surface

Proceed with plant mixing

Structural

Is cold *in situ* mixing a viable option?

Yes

Use *in situ* cold mix asphalt

No

Is plant technology available to facilitate high rates

Yes

Maximise energy efficiency in mixing with plant technology

No

Is lower-temperature mixing feasible?

No

Hot mix asphalt with <10% RA and compensate for the cold fed RA

Yes

Select an appropriate, sustainable LTA

Mix at lower-temperature

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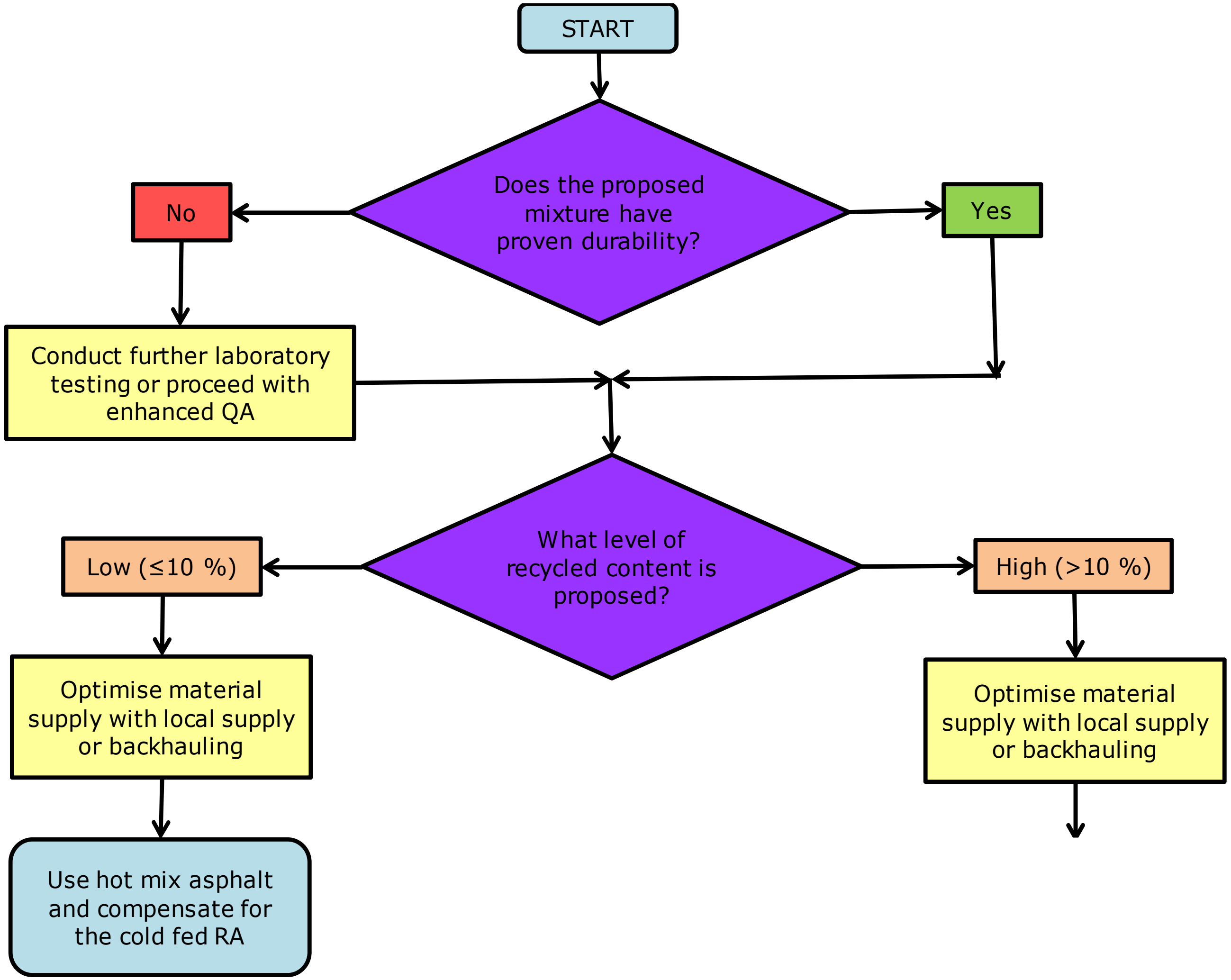
Thank You

Any questions?


START
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No
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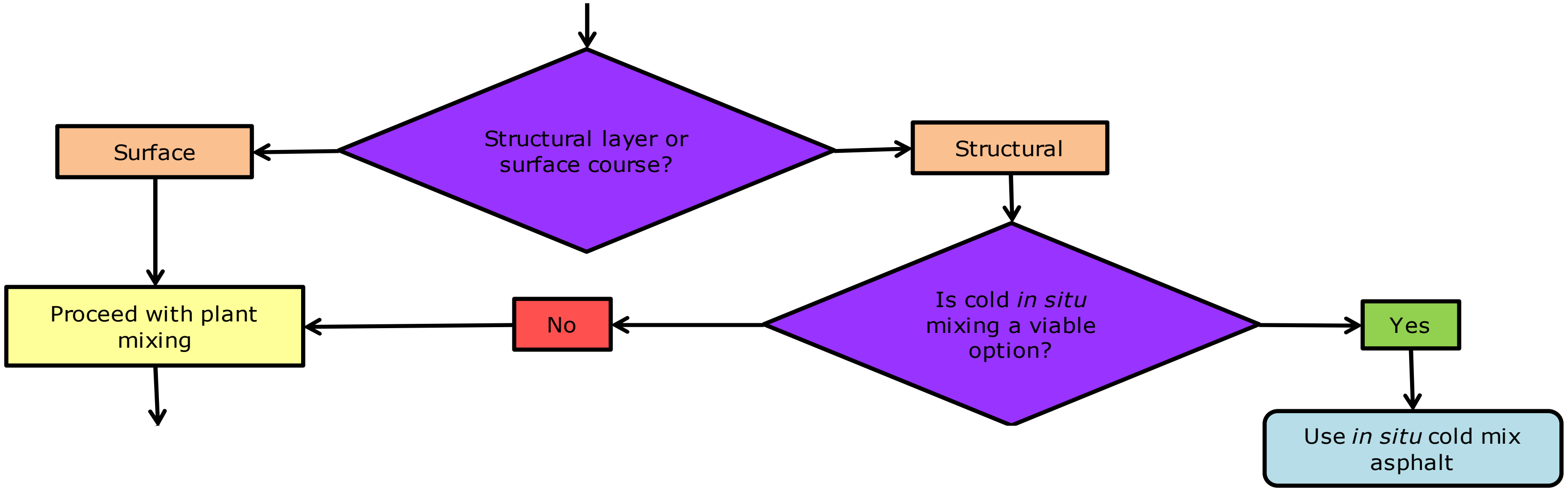
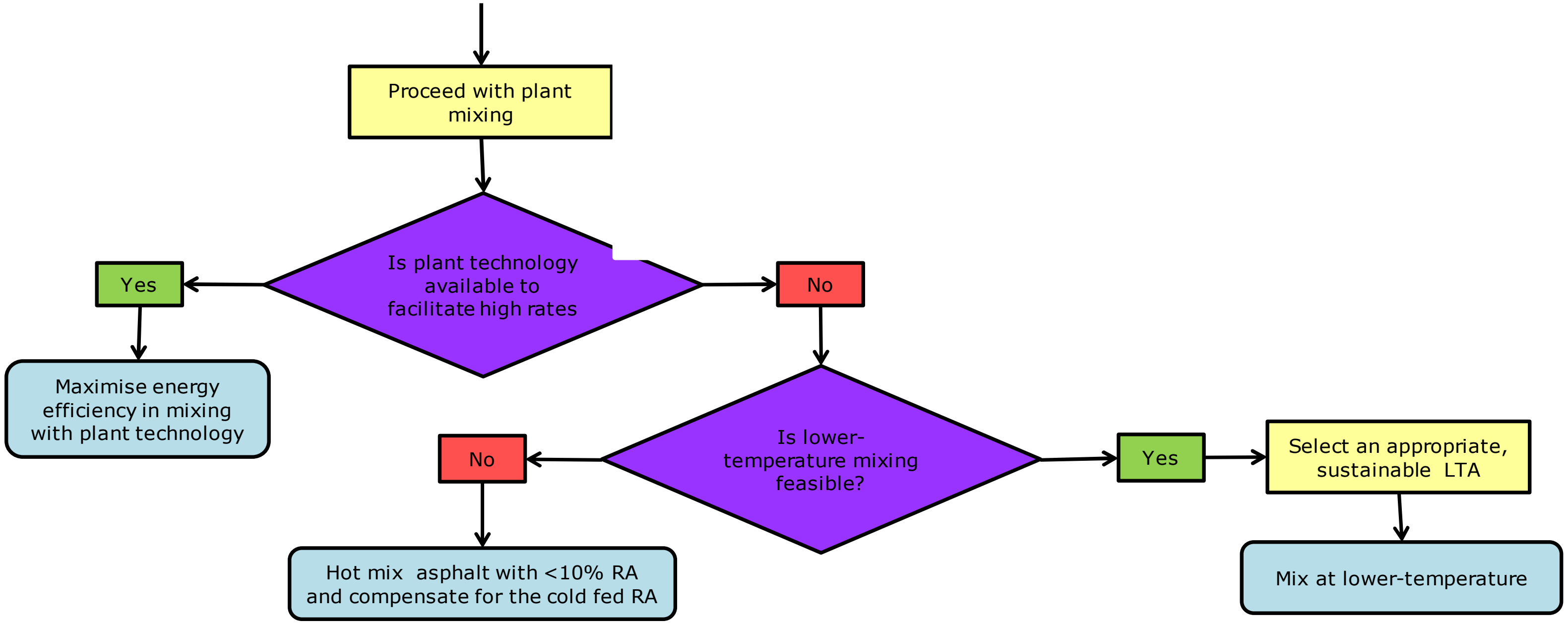

Structural layer or surface course?
Surface
Structural
Proceed with plant mixing
No
Is cold *in situ* mixing a viable option?
Yes
Use *in situ* cold mix asphalt



Proceed with plant mixing

Is plant technology available to facilitate high rates

Yes

Maximise energy efficiency in mixing with plant technology

No

Is lower-temperature mixing feasible?

No

Hot mix asphalt with <10% RA and compensate for the cold fed RA

Yes

Select an appropriate, sustainable LTA

Mix at lower-temperature