Pavement Whole Life Cost

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Contents

AECOM Road Asset Management

- Team of over 110 staff based in the UK
- Research into practice
- Asset management and whole life cost
- Cutting edge investigation, survey and data collection techniques
- Multi skilled resource with flexibility and competencies to work cross sector
- UKAS accredited lab including pavement test facility
- Materials performance and design expertise
- One stop shop

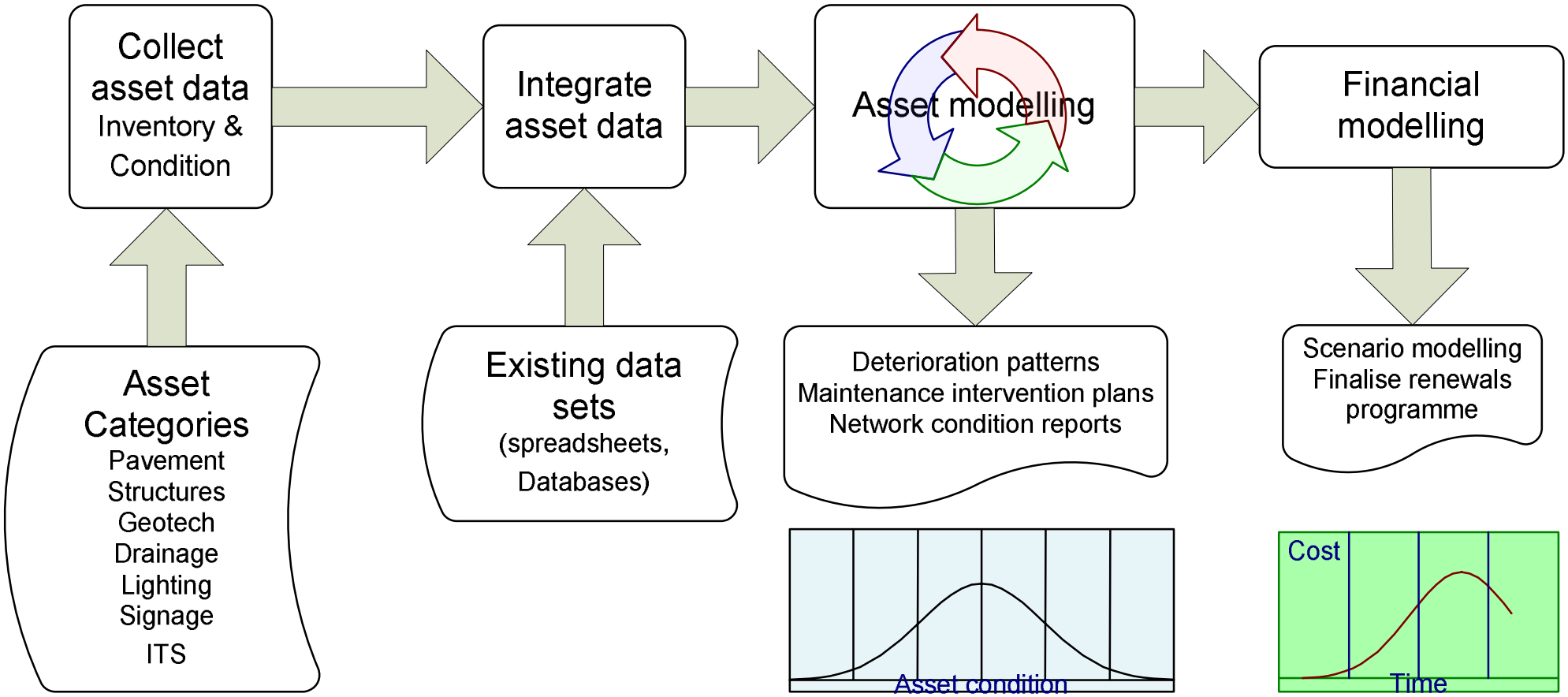
AECOM Research Laboratory and Pavement Surveys

Asset Management and Whole Life Cost Principles

Road Asset Management

– Develop maintenance strategy and programme to meet the authority performance requirements and financial constraints

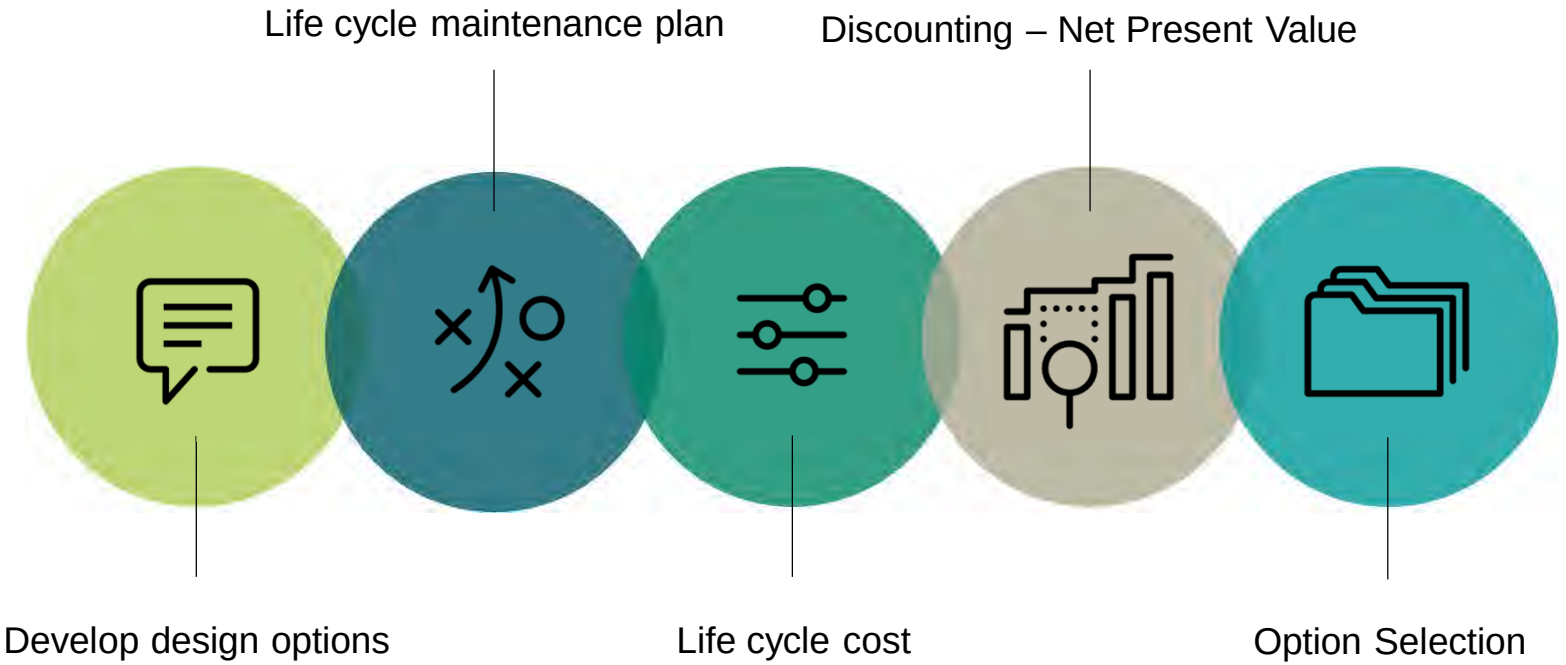
Road Asset Management: Life Cycle Considerations



Project Whole Life Cost

- Whole life cost analysis is used to compare economic efficiency of different investment options (e.g. pavements)
- The analysis period is typically 60 years
- Requires design input to determine how long pavement design and/or rehabilitation will last

Whole Life Cost Process



Whole Life Cost Elements

- Pavement initial construction or rehabilitation cost
  - Expected service life of initial pavement structure
- Future maintenance and rehabilitation costs
  - Expected timings/performance characteristics of future treatments
- Economic discount rate
- Expected residual value at the end of the design period, e.g. recycling

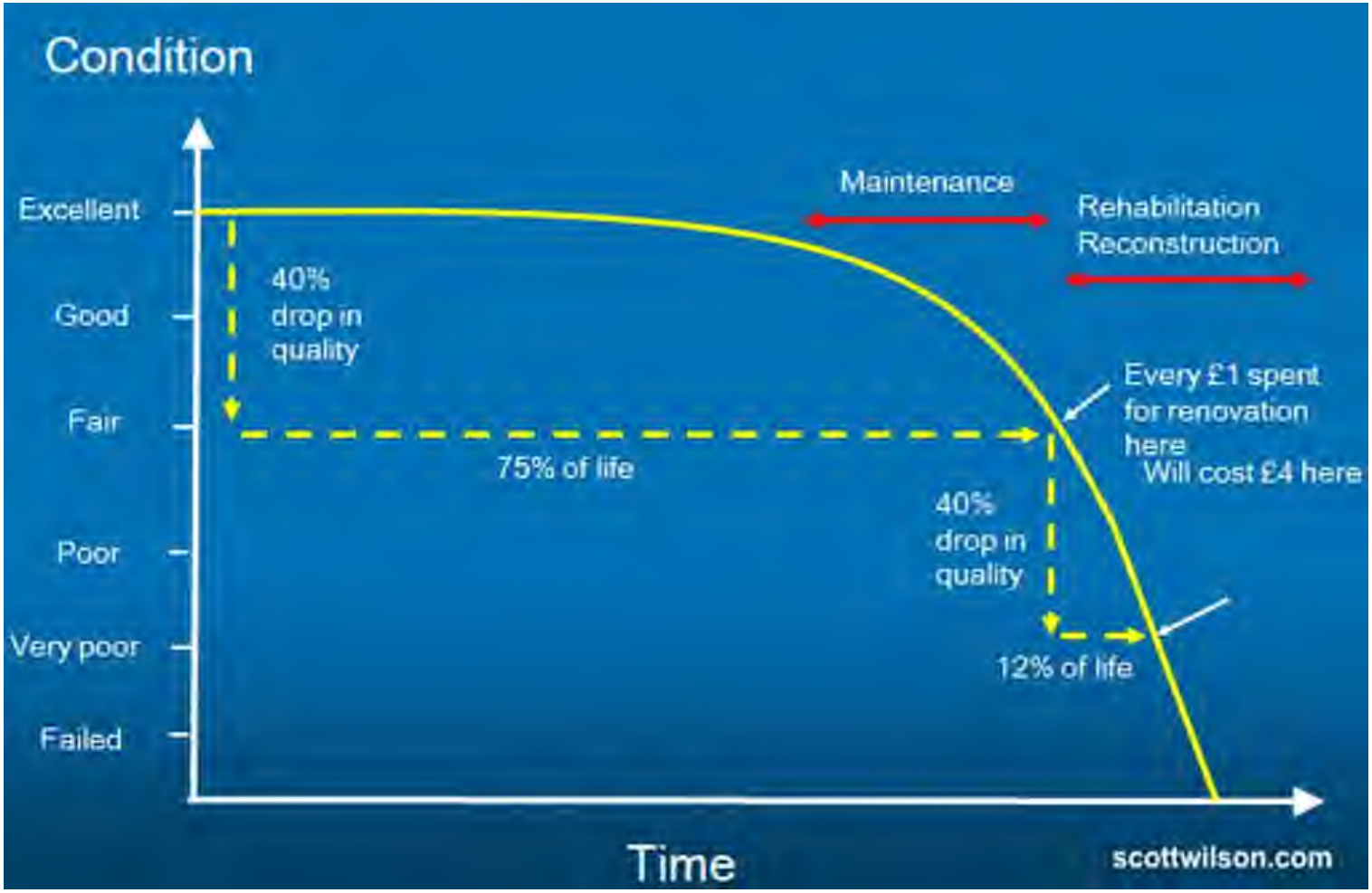
- User costs, as a result of extra time delay, increased vehicle operating costs, or increased accidents

Pavement Performance Requirements

- Skid resistance
- Ride and surface quality
- Structural bearing capacity to carry traffic load

Pavements deteriorate and require maintenance

Pavement Deterioration

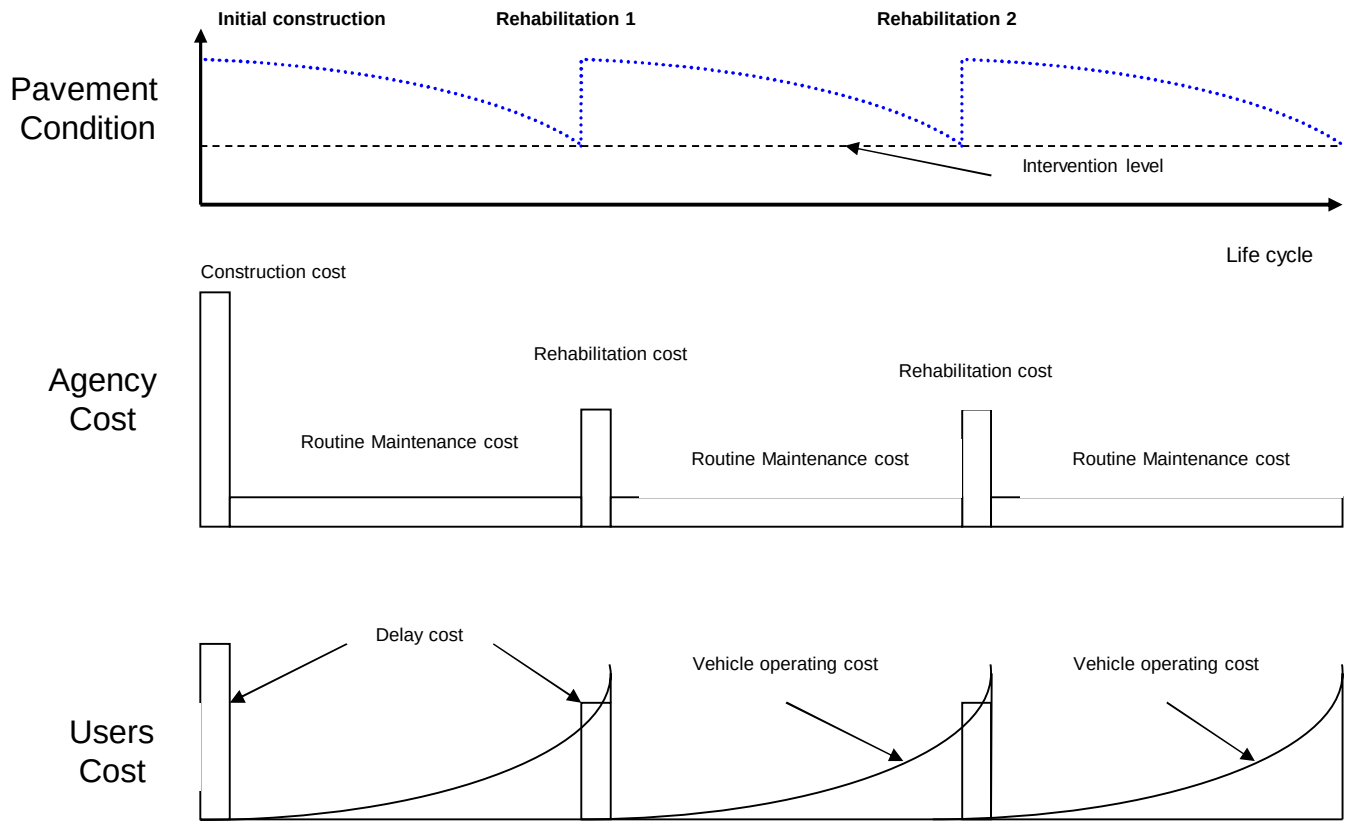


Pavement Deterioration

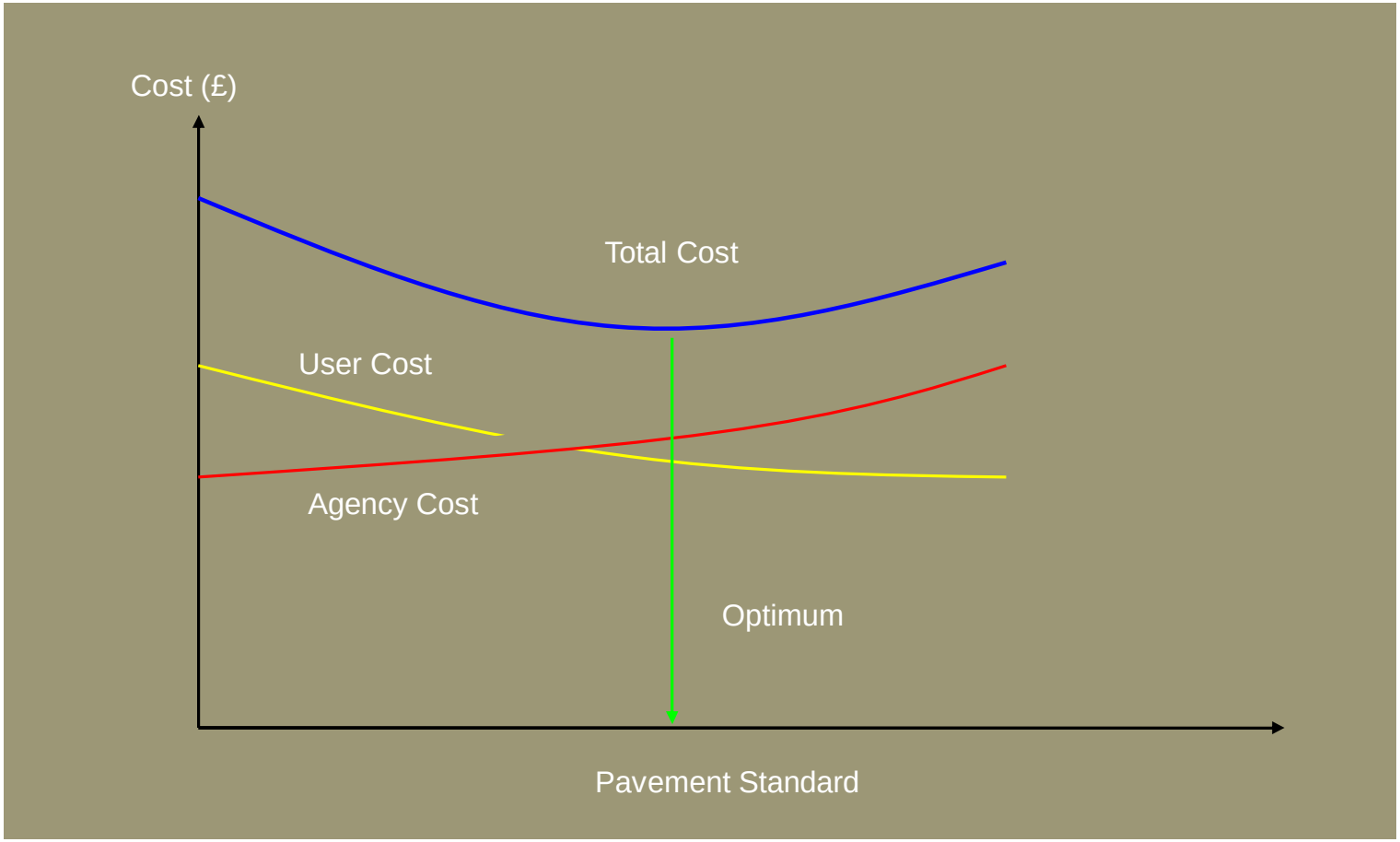
- Pavements deteriorate with time under loading and from environmental (temperature and moisture) variations

- Predicting deterioration is a challenge!
  - Vehicle type, loading magnitude and future growth are unknown
  - Environmental variations are unknown
  - Material properties are function of temperature and moisture
  - Materials age and properties change with time

Whole Life Cost Modelling



Whole Life Cost Modelling



Pavement Design and Construction

CD 226 Design for New Pavement Construction

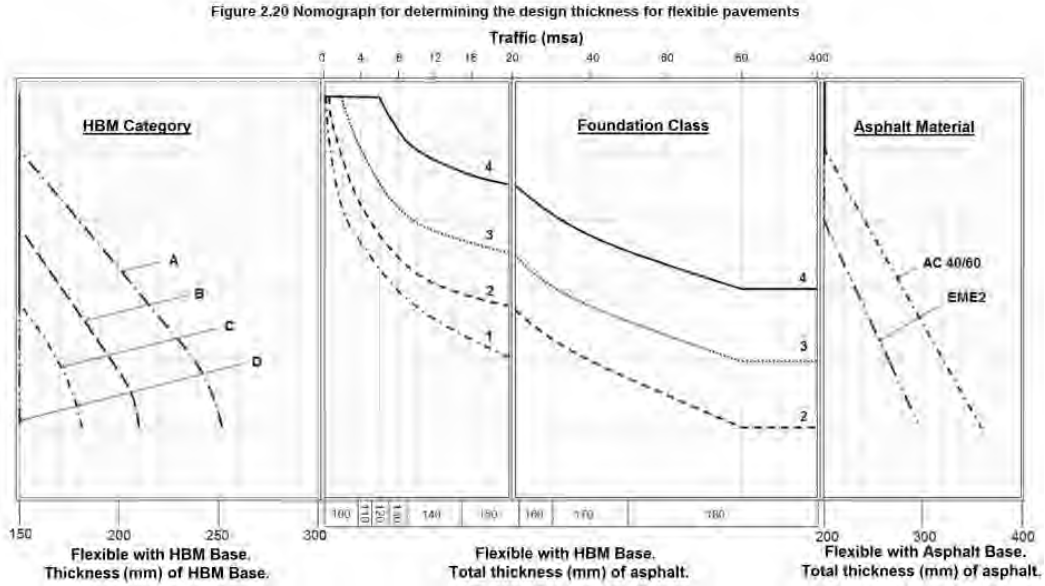
- New pavement designs shall be carried out using a minimum of three options
  - Flexible with an asphalt base
  - Flexible with an HBM base
  - At least one type of rigid pavement should be considered
- The design report shall include details and results of the whole life cost analysis

Pavement Design

- National Highways 3D Process (Develop, Design, Deliver)

- Ground condition, future traffic and design period
- Design new pavement options (CD226)
    - Typically for 40 years
    - Long life pavement (LLP) - No structural treatment
    - Staged design? (not typical in the UK)

- Specify the materials (Appendix 7/1)
- Calculate the material quantities for the schemes
    - Section length
    - Number of lanes and lane width
    - Hard shoulder / Hard strip / Central reserve
    - Slip roads



CD 226 Rigid Pavement Design Charts

Figure 2.26 Nomograph for determining concrete layer design thickness for continuously reinforced concrete pavements (CRCB and CRCP)

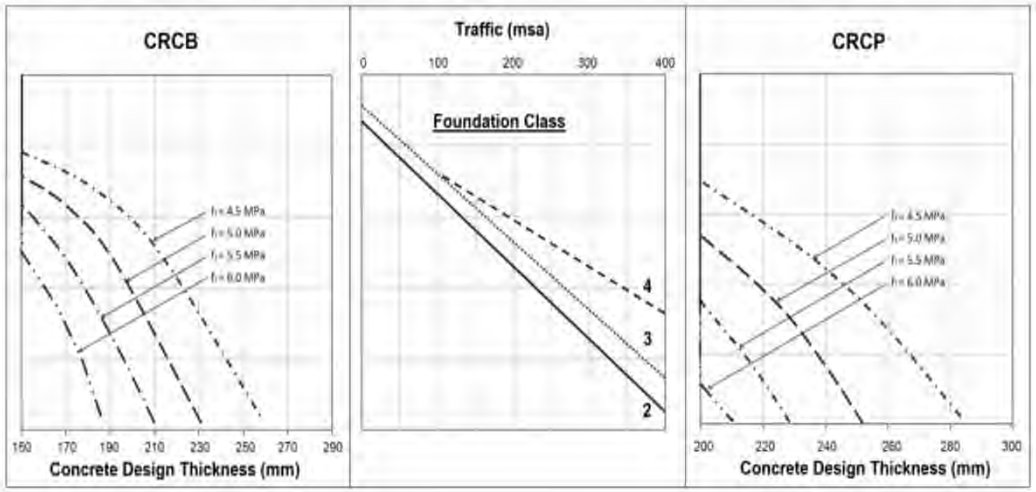
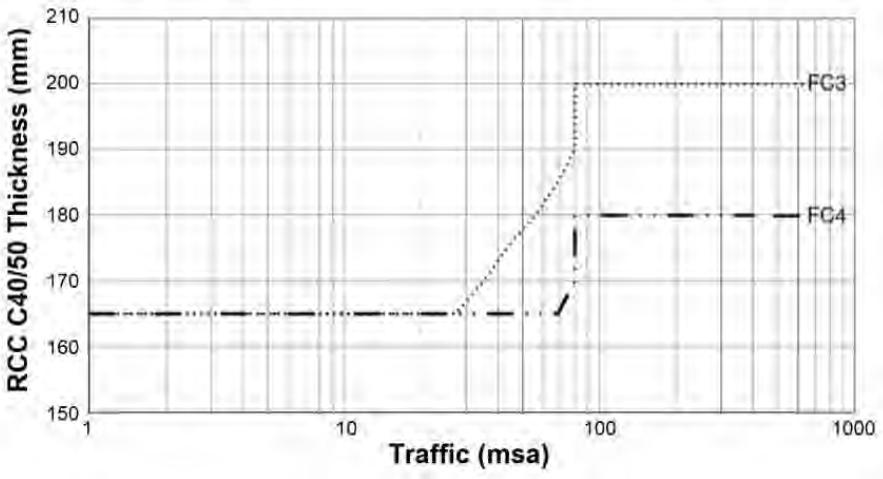
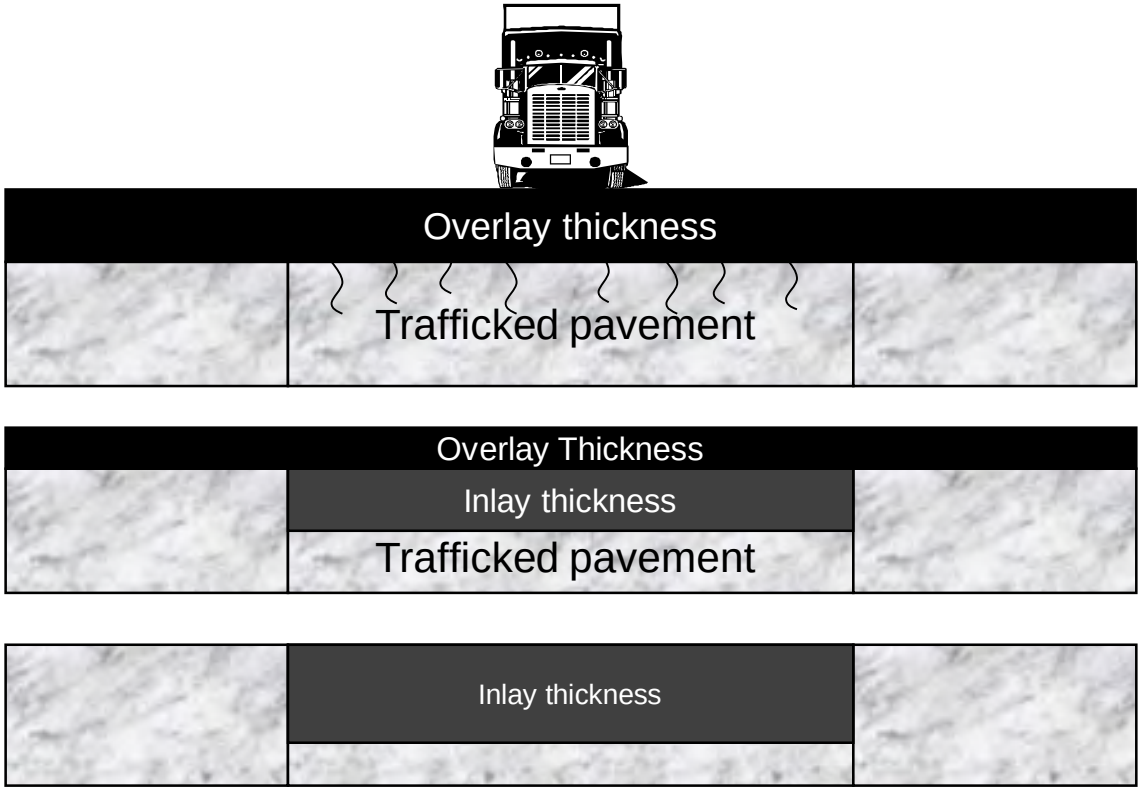


Figure 2.40 Design thickness for the concrete layer in roller compacted concrete (RCC) pavements



Pavement Rehabilitation Design

- Existing pavement condition (surveys and testing), future traffic and design period (CD227)
- Design pavement rehabilitation options
    - Typically for 20 years
    - Upgrade to LLP
    - Overlay
    - Inlay
    - Partial reconstruction (bound layers)
    - Full reconstruction
- Specify the materials (Appendix 7/1)
- Calculate the material quantities for the schemes



Pavement Construction

Design Option	Pavement Type P1		Pavement Type P2		Pavement Type P3	
	Construction	Initial Cost	Construction	Initial Cost	Construction	Initial Cost
Option A Fully Flexible	45mm HRA Surface 55mm Asphalt Binder 180mm Asphalt Base 350mm Granular Subbase 250mm Capping	£/m^2	45mm HRA Surface 55mm Asphalt Binder 210mm Asphalt Base 350mm Granular Subbase 250mm Capping	£/m^2	45mm HRA Surface 55mm Asphalt Binder 220mm Asphalt Base 350mm Granular Subbase 250mm Capping	£/m^2
Option B Flexible Composite HBM B	45mm HRA Surface 95mm Asphalt Binder 170mm HBM B 350mm Granular Subbase 250mm Capping	£/m^2	45mm HRA Surface 55mm Asphalt Binder 60mm Asphalt Base 190mm HBM B 350mm Granular Subbase 250mm Capping	£/m^2	45mm HRA Surface 55mm Asphalt Binder 70mm Asphalt Base 200mm HBM B 350mm Granular Subbase 250mm Capping	£/m^2
Option C Flexible Composite HBM C	45mm HRA Surface 95mm Asphalt Binder 150mm HBM C 350mm Granular Subbase 250mm Capping	£/m^2	45mm HRA Surface 55mm Asphalt Binder 60mm Asphalt Base 170mm HBM C 350mm Granular Subbase 250mm Capping	£/m^2	45mm HRA Surface 55mm Asphalt Binder 70mm Asphalt Base 170mm HBM C 350mm Granular Subbase 250mm Capping	£/m^2

Pavement Maintenance

Maintenance based on Condition

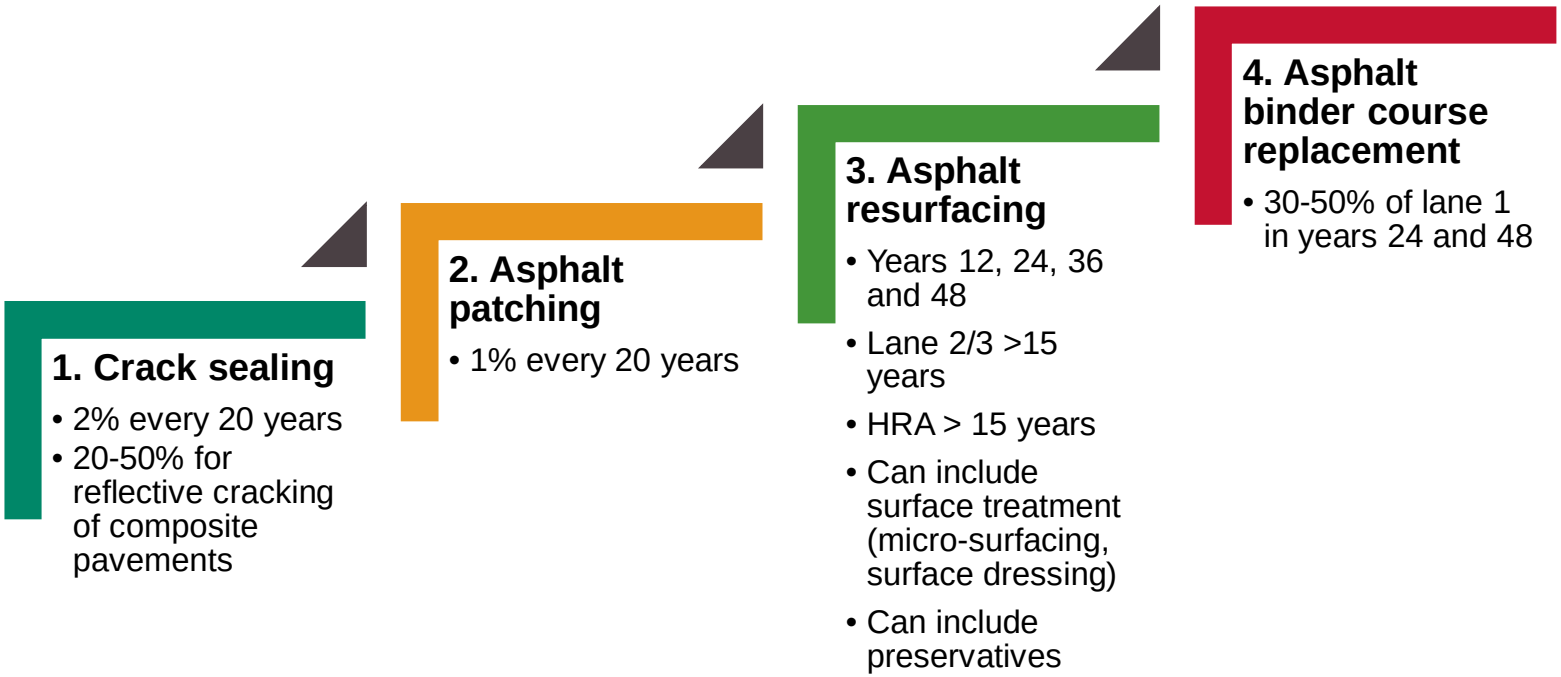
- **Reactive** maintenance for safety considerations
- **Routine** maintenance including crack sealing, patching and drainage improvement (durability)

- **Surface treatment** to improve skid resistance and seal any cracks (friction and durability)
- **Resurfacing** (replacement/recycling) to improve skidding, to provide good ride quality and protect the lower pavement layer
- **Thick overlay/inlay** to improve pavement structural life
- Partial or full **reconstruction**

Flexible pavement routine and planned maintenance

Long Life Pavement

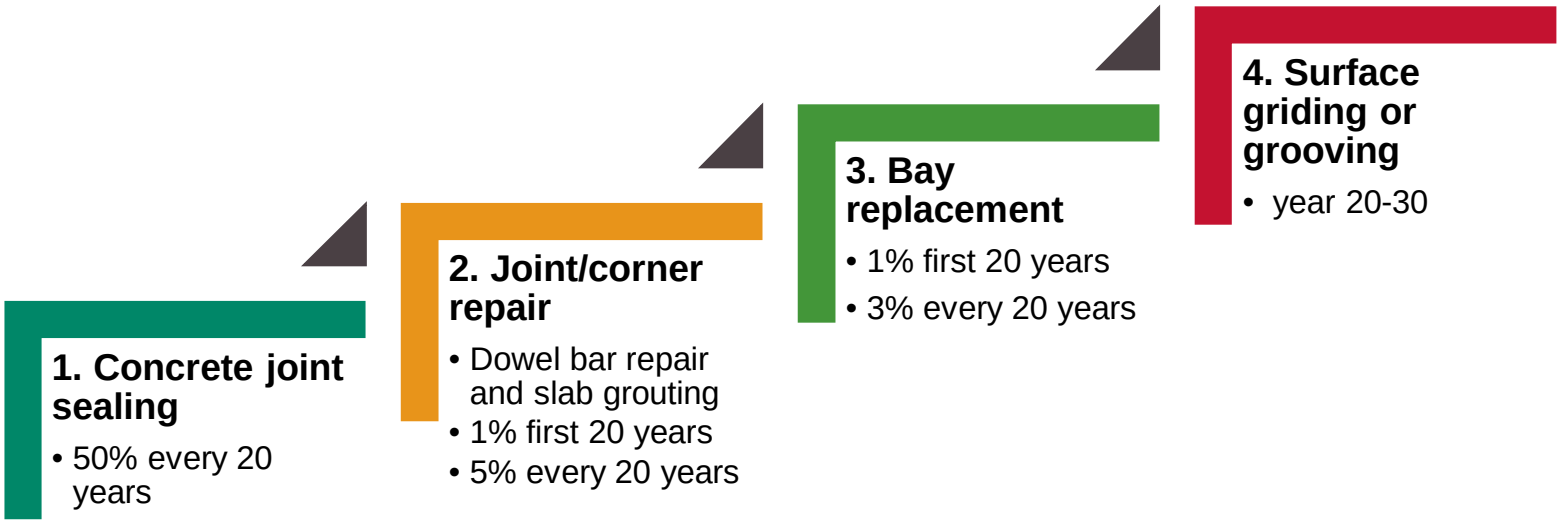
Based on performance / experience, traffic loading and environmental condition



Jointed concrete pavement routine and planned maintenance

Long life pavement

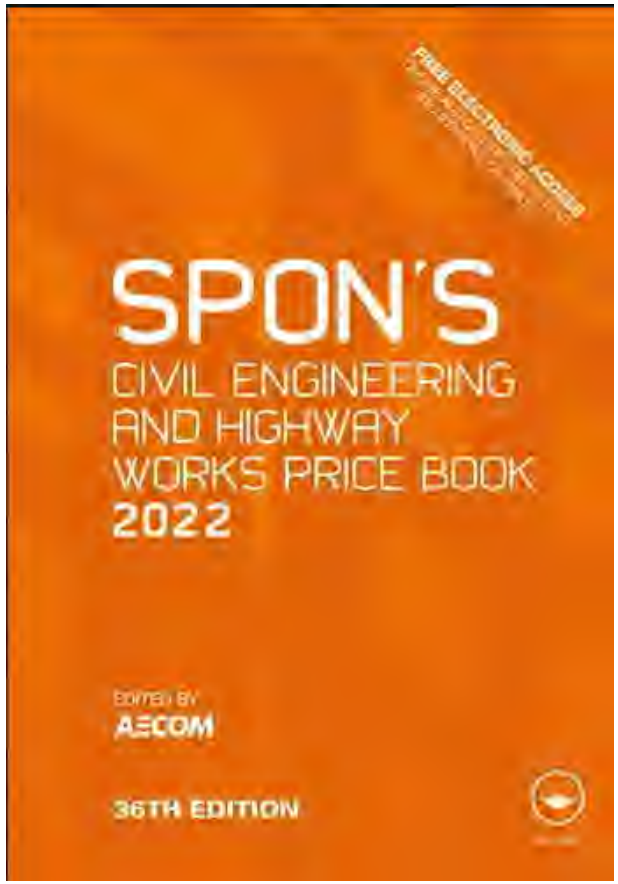
Based on experience, traffic loading and environmental condition



Unit rates and Net Present Value

Pavement Materials Unit Rates

- Based on project location, materials availability and commercial considerations
- However, during the preliminary design data might not be available
- Spon’s Civil Engineering and Highways Works Price Book
- Updated annually
- Does not include a comprehensive list of all materials
- Assumptions are needed



Example of Material Unit Rates

Material Ref.	Material Description	Layer Thickness (mm)	Unit	Rate (£)
Subbase (150MPa)	Granular material DfT Type 1 [3]	75	m^3	£39.89
Subbase (150MPa)		100	m^3	£41.22
Subbase (150MPa)		150	m^3	£42.55
Subbase (150MPa)		200	m^3	£43.88
Capping (75MPa)	Imported selected granular fill, DfT Class 6F (1.9 t/m3) [4]	-	m^3	£45.97
	Cement bound granular mixture Subbase; spread and graded	75	m^3	£104.40
		100	m^3	£105.32
		200	m^3	£107.06
C3/4(500MPa)	0.9	75	m^3	£93.96
C3/4(500MPa)	0.9	100	m^3	£94.79
C3/4(500MPa)	0.9	200	m^3	£96.35
C6/8(1000MPa)	1	75	m^3	£104.40
C6/8(1000MPa)	1	100	m^3	£105.32
C6/8(1000MPa)	1	200	m^3	£107.06
CBGM Cat B	1.1	75	m^3	£114.84
CBGM Cat B	1.1	100	m^3	£115.85
CBGM Cat B	1.1	200	m^3	£117.77
CBGM Cat C	1.2	75	m^3	£125.28
CBGM Cat C	1.2	100	m^3	£126.38
CBGM Cat C	1.2	200	m^3	£128.47

Note: The rates are extracted from **Spon's Civil Engineering and Highways Works Price Book**. Factors of the Spon's CBGM unit rate are assumed for HBM Category A, B and C.

Example of Material Unit Rates

Material Ref.	Material Description	Layer Thickness (mm)	Unit	Rate (£)
	HRA binder course [6]	60	m^2	£17.82
		80	m^2	£19.91
HRA (Clause 943)	1.3	60	m^2	£23.17
HRA (Clause 943)	1.3	80	m^2	£25.88
RCC	RCC [7]	200	m^2	£31.03
CRCP: flexural strength 5.5 MPa	In situ concrete - Designed Concrete Strength RC 40/50	250	m^2	£141.02
CRCP: flexural strength 5.5 MPa		220	m^2	£125.63
CRCP: flexural strength 5.5 MPa		200	m^2	£115.74
CRCP: flexural strength 5.5 MPa		170	m^2	£102.35
CRCP: flexural strength 5.5 MPa		160	m^2	£97.32
	Fly ash bound mixture 1 and hydraulic road blinder bond mixture 1 [8]	100	m^2	£22.44
		150	m^2	£29.81
		200	m^2	£37.18
AC 32 dense bin 40/60 des	Asphalt Base Course	100	m^2	£22.20
AC 32 dense bin 40/60 des		150	m^2	£29.46
AC 32 dense bin 40/60 des		200	m^2	£36.73
AC 20 dense bin 40/60 des	Asphalt Binder Course [9]	50	m^2	£14.48
AC 20 dense bin 40/60 des		100	m^2	£21.28
EME2	1.3	50	m^2	£18.82
EME2	1.3	100	m^2	£27.66
TSCS	Asphalt Surface Course	30	m^2	£10.22
TSCS		50	m^2	£15.73

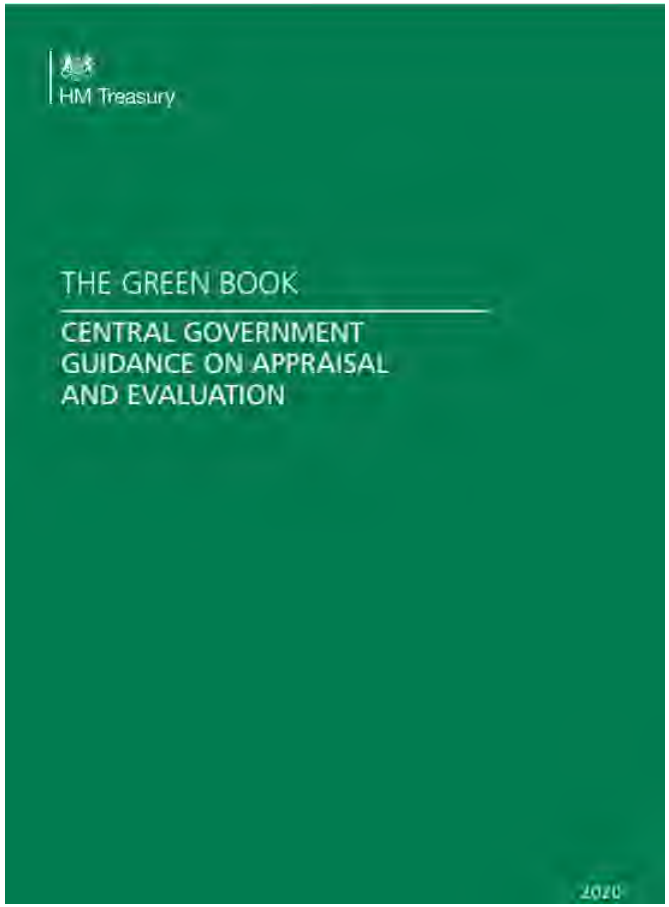
Note: The rates are extracted from **Spon's Civil Engineering and Highways Works Price Book**. Factors of the Spon's CBGM unit rate are assumed for HBM Category A, B and C.

Example of Construction Cost

Pavement	Layer	Material Ref.	Thickness (mm)	Rate	Unit	Cost	Total Cost (£)
Flexible with AC base	Surface	TSCS	40	£12.98	m2	£844,673	£4,712,179
	Binder Course & Base	AC 32 dense bin 40/60 des	285	£49.08	m2	£3,195,032	
	Performance FC2	Subbase (150MPa)	230	£44.91	m3	£672,474	
Flexible with EME base	Surface	TSCS	40	£12.98	m2	£844,673	£4,814,331
	Binder Course & Base	EME2	230	£50.65	m2	£3,297,185	
	Performance FC2	Subbase (150MPa)	230	£44.91	m3	£672,474	
RCC	Surface	TSCS	40	£12.98	m2	£844,673	£4,956,868
	Binder	HRA (Clause 943)	50	£21.81	m2	£1,419,668	
	Concrete Base	RCC	200	£31.03	m2	£2,020,053	
	Performance FC2	Subbase (150MPa)	230	£44.91	m3	£672,474	
Flexible with CBGM Cat B Base	Surface	TSCS	40	£12.98	m2	£844,673	£4,874,594
	Binder Course & Upper Base	AC 32 dense bin 40/60 des	140	£28.01	m2	£1,823,473	
	HBM Base	CBGM Cat B	200	£117.82	m3	£1,533,975	
	Performance FC2	Subbase (150MPa)	230	£44.91	m3	£672,474	
Flexible with CBGM Cat CB Base	Surface	TSCS	40	£12.98	m2	£844,673	£4,754,996
	Binder Course & Upper Base	AC 32 dense bin 40/60 des	140	£28.01	m2	£1,823,473	
	HBM Base	CBGM Cat C	170	£127.80	m3	£1,414,377	
	Performance FC2	Subbase (150MPa)	230	£44.91	m3	£672,474	
CRCP	Surface	TSCS	40	£12.98	m2	£844,673	£9,095,396
	CRCP	CRCP: flexural strength 5.5 MPa	200	£116.41	m2	£7,578,250	
	Performance FC2	Subbase (150MPa)	230	£44.91	m3	£672,474	

Net Present Value

- Discounted annual rates
- The Green Book - Central Government Guidance on Appraisal and Evaluation
    - 3.5% is recommended for the first 30 years
    - 3% is recommended for post year 30 respectively



Whole life cost model example

Year	Option 1: Fully Flexible Pavement		Option 3: Composite Flexible Pavement		Option 9: Roller Compacted Concrete	
	Actual cost	Discounted Cost	Actual cost	Discounted Cost	Actual cost	Discounted Cost
2023	£34,966,787	£34,966,787	£32,696,332	£32,696,332	£32,012,269	£32,012,269
2024						
2025						
2026						
2027						
2028						
2029						
2030						
2031						
2032						
2033						
2034						
2035	£3,462,769	£2,291,603	£3,462,769	£2,291,603	£4,398,034	£2,910,545
2036						
2037						
2038						
2039						
2040						
2041						
2042						
2043						
2044						
2045						
2046						
2047	£5,070,579	£2,220,696	£6,142,452	£2,690,131	£8,625,324	£3,777,522
2048						
2049						
2050						
2051						
2052						
2053						
2054						
2055						
2056						
2057						
2058						
2059	£3,462,769	£1,194,768	£3,462,769	£1,194,768	£8,625,324	£2,976,016
2060						
2061						

Summary and Conclusions

- Whole life cost appraisal is required for new and rehabilitated pavement projects
- To compare different investment options
  - Pavement design
  - Initial construction cost
  - Life cycle maintenance plan
  - Life cycle maintenance cost
  - Discounted rates
- Results should be used with other factors such as project sustainability, constructability, construction programme, durability and users cost for pavement selection and detailed design

Questions?