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Rolling Resistance and Traffic Delay Impact on a Road Pavement Life Cycle Carbon Footprint Analysis

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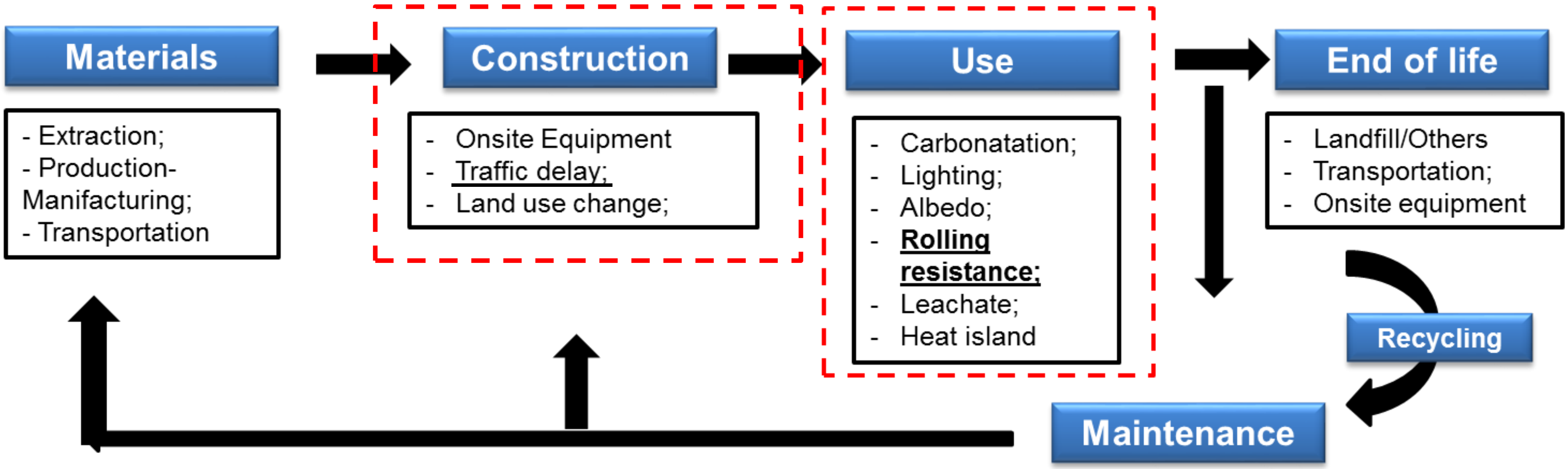
INTRODUCTION

- **Pavement LCA**



Adapted from (Santero et al. 2011)

Growing interest in pavement LCA

Limitations and uncertainties

Traffic delay

Traffic delay results from lane or road closures at construction and maintenance work zones due to queueing or detours, around the construction site.

2 step method

(Traffic model + emission model):

Sophisticated approach:

Microsimulation model (average queue length and the instantaneous speed of individual vehicles). Generally, it includes an emission model.

Simplified approach:

Demand-Capacity (D-C) model, defined in the Highway Capacity Manual, (work zone average queue and speed). An emission model is used, based on the output provided by the traffic models.

↓

HCM not suitable for congested network

↓

A computational approach to analyse the user cost of work zone traffic delay, in life cycle cost analysis (LCCA) developed by the FHWA (Walls III and Smith 1998).

Traffic delay

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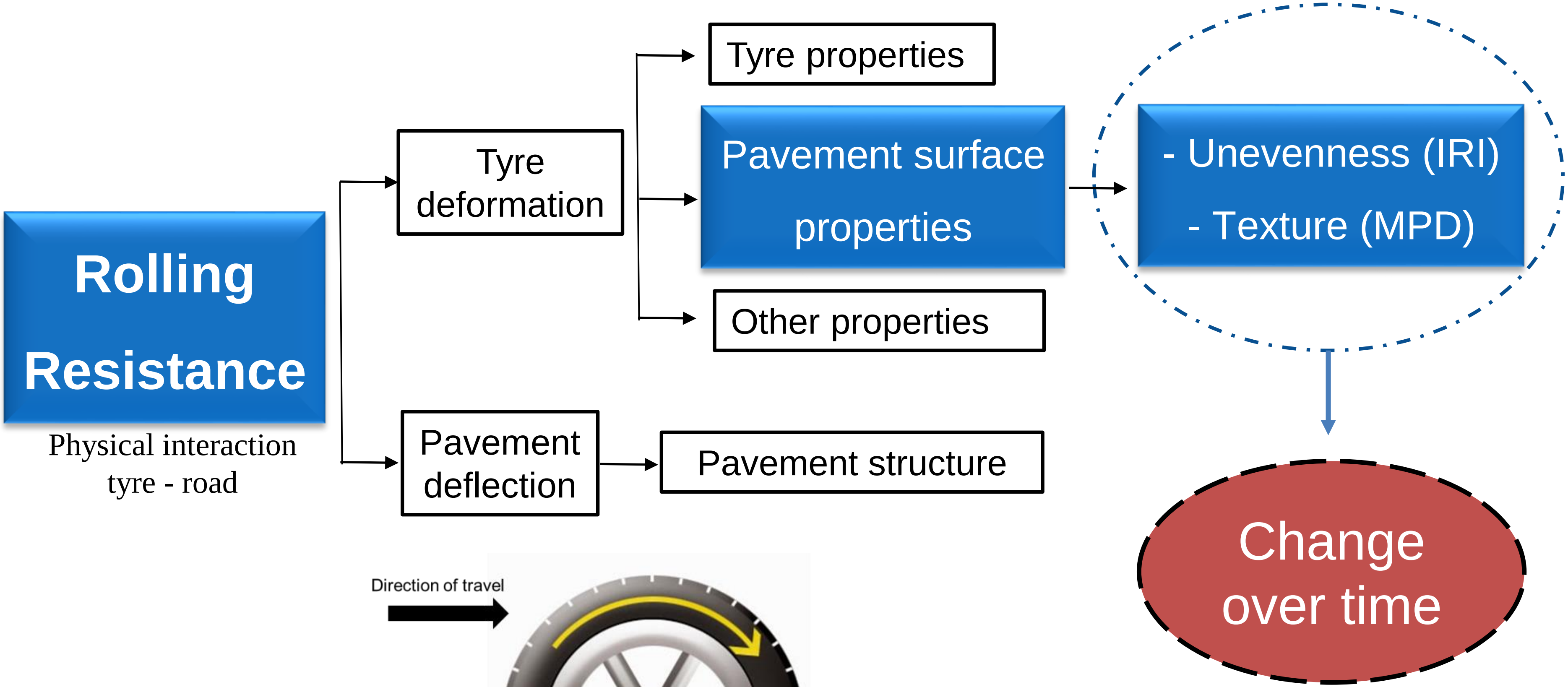
Sophisticated approach

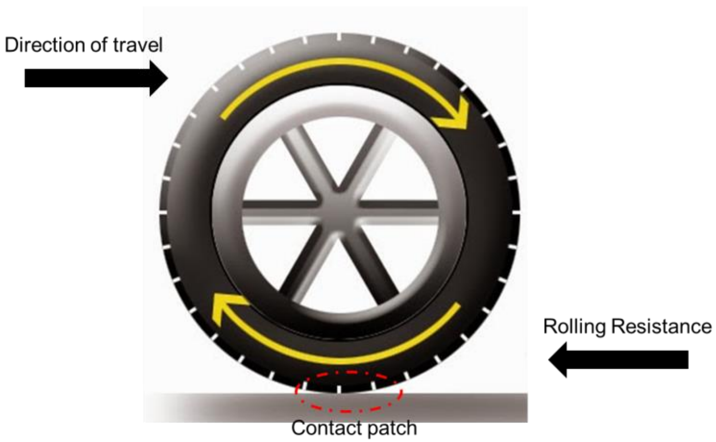
- flexible and accurate, producing disaggregated traffic data and it can readily include the wider network
- incorporated in commercial software that increase the cost of the analysis and require detailed traffic data, which can limit the size of the network model

Simplified approach

- ease of implementation, requiring limited data input (hourly traffic volume, capacity and Traffic Management (TM) layout).
- accuracy of the results: TM scheme complex or area of impact extensive

Rolling Resistance





Rolling Resistance

- Calculating the impact of pavement surface properties on the Rolling Resistance and then on vehicle fuel consumption is complex.

- Different Rolling Resistance models and incomplete knowledge related to the influence of specific parameters on the results generates a high level of uncertainty.

- In the UK
  - no studies involving national case studies on the impact of the rolling resistance on the LCA of a pavement;
  - lack of general pavement deterioration models (deterioration rate of IRI and MPD).

Aims and Research questions

Explore the INFLUENCE OF THE MODEL USED AND THE ASSUMPTIONS made to estimate the increased emissions due to work zone traffic delay and the Rolling Resistance on pavement LCA results.

- Are the rolling resistance models ready for **implementation** in pavement LCA? Can they be **applied in the UK**? How do pavement deterioration and the model uses affect the results?

- Does **the level of sophistication** of a traffic model to evaluate the traffic delay impact the LCA results? How do the choices made by the modeller impact the results?

Methodology and case study

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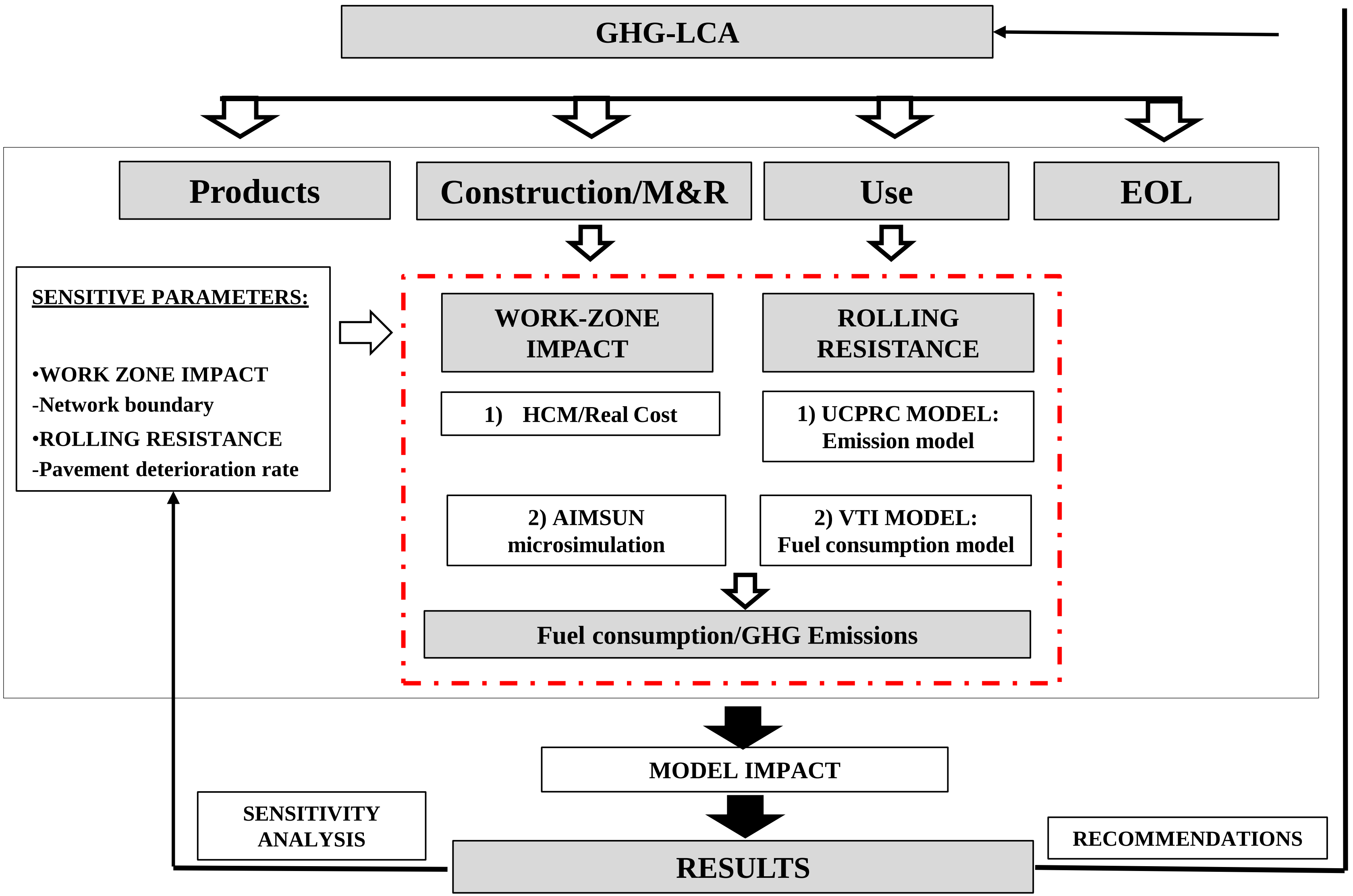
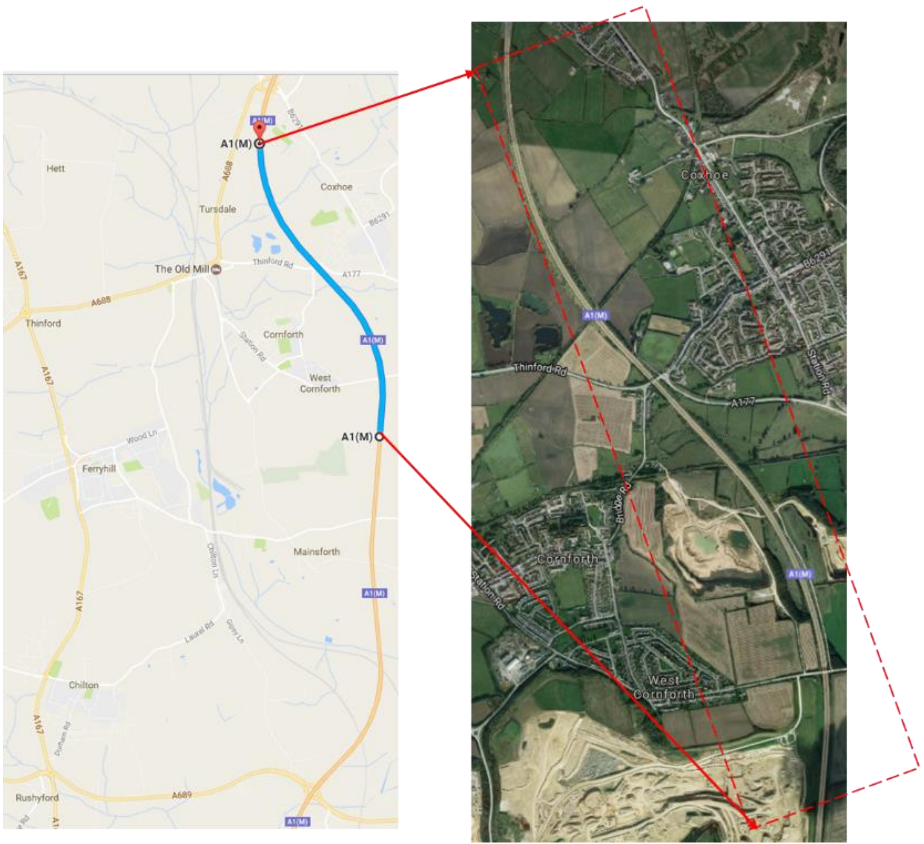


Methodology and case study

4 km section of the dual carriageway A1 (M) motorway located in the North East of England, UK.

The **original construction** included a chipped hot rolled asphalt surface course.

In 2009, a 40 mm overlay of thin surfacing was applied to a 4 km section of both carriageways.

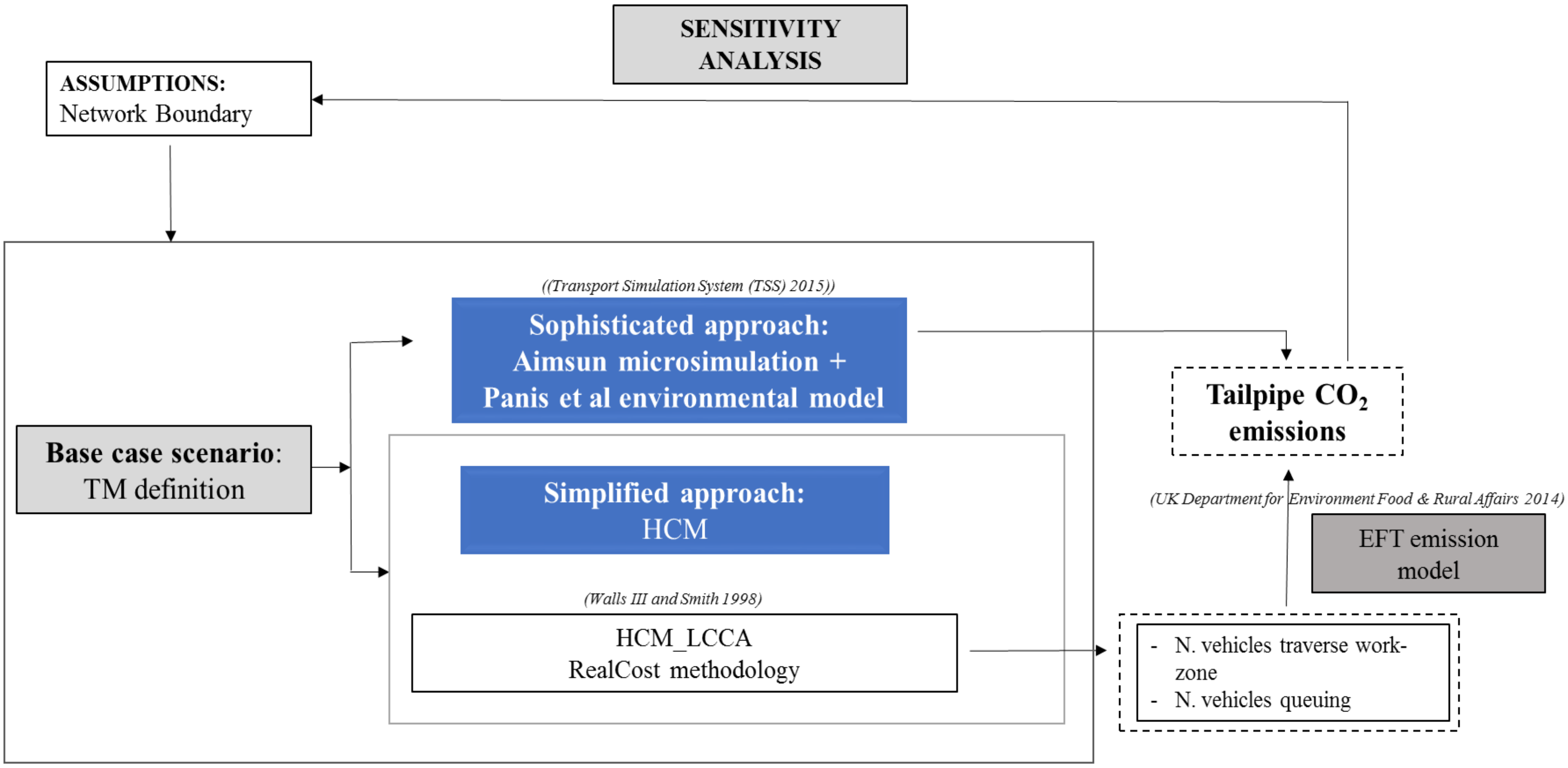


Case study	A1 (M)
AADT	51502
Road type	Motorway dual carriageway
Construction year	2009
Analysis period	20
Surface materials	40 mm overlay of thin surfacing

Methodology and case study

Traffic delay

To estimate the additional emissions from traffic during road works, both the emissions during normal conditions (no work zone) and maintenance conditions (work-zone) were calculated.



Methodology and case study

Traffic delay

TM strategy

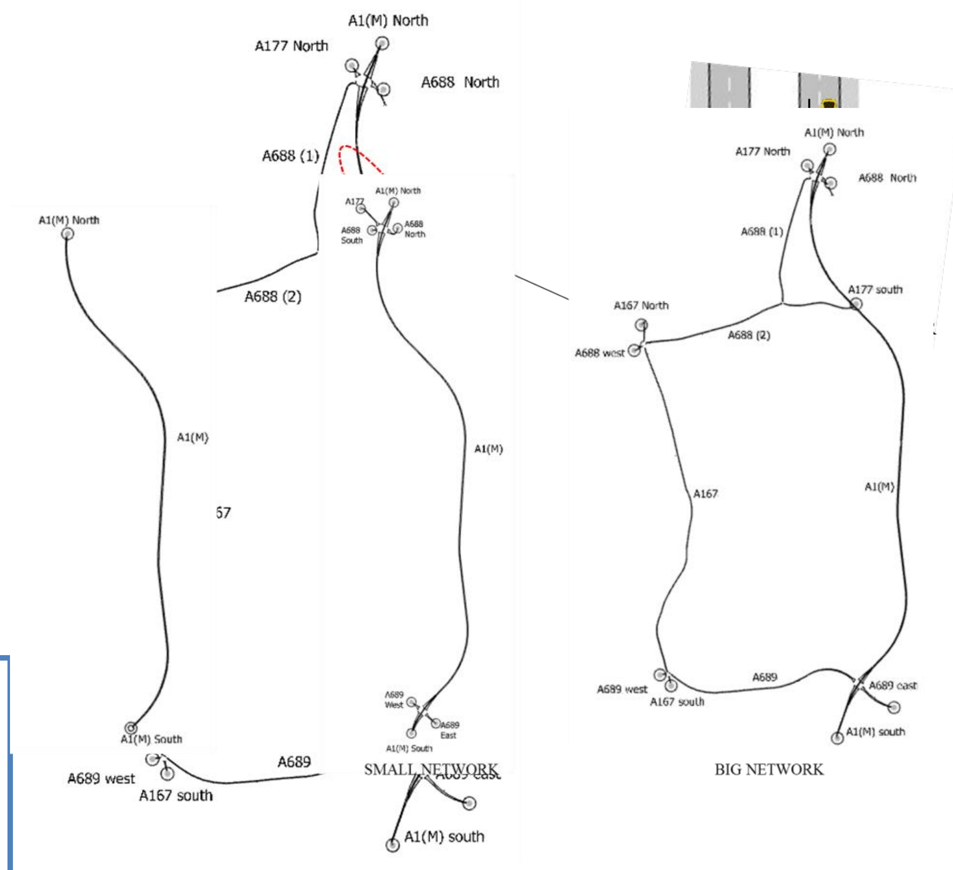
- carriageway closure and contraflow on the other carriageway
- 24 hours to install the 40mm Thin Surface Course per 1 km, three days to deploy the TM and three days to remove it.

17 days work to resurface both carriageways.

Network boundary

The traffic modelling requires the identification of the extent of the network impacted by the work zone. For a comprehensive understanding, the modelling should cover the whole network affected.

Based on Jean Lefebvre (UK) Technical Centre information



Methodology and case study

Rolling Resistance

University of California Pavement Research Center - UCPRC MODEL

$$T_{CO_2} = a_1 \times MPD + a_2 \times IRI + Intercept$$

(Wang et al. 2014)

Swedish National Road And Transport Research Institute - VTI MODEL

$$F_r = m_1 \times g \times (0.00912 + 0.0000210 \times IRI \times V + 0.00172 \times MPD)$$

Hammarström et al. 2012

$$F_{cs} = 0.286 \times \left(\begin{array}{l} (1.209 + 0.000481 \times IRI \times V + 0.394 \times MPD)^{1.163} \\ + 0.000667 \times V^2 + 0.0000807 \times ADC \times V^2 \\ - 0.00611 \times RF + 0.000297 \times RF^2 \end{array} \right) \times V^{0.056}$$

Methodology and case study

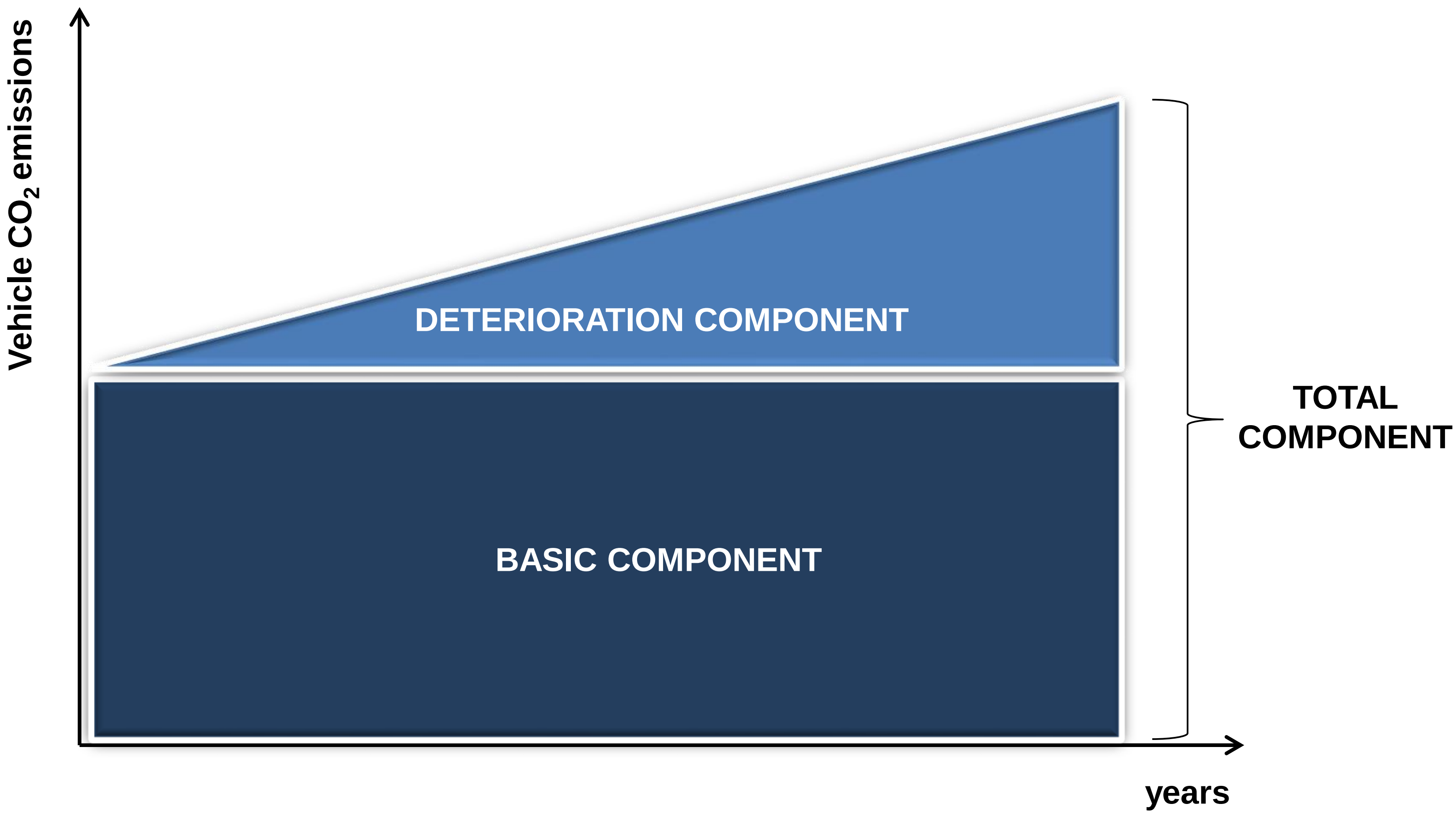
- INPUT PARAMETER:
- pavement condition deterioration rate with time (IRI and MPD)

SENSITIVITY ANALYSIS
3 scenarios of deterioration

- No deterioration
- Average deterioration
- Worst deterioration

Case study	Scenario	MPD mm	IRI m/km
A1	Average deterioration	1.6-0.6	1.0-2.3
	Worst deterioration	1.3	1.0-5.0
	No deterioration	1.5	1

Methodology and case study



Results_Traffic delay

Model comparison

	Emission of CO_2 (ton)	
	Microsimulation	D-C model
TM (17 days)	48.58	329.67
Per day (average)	2.86	19.39

D-C MODEL
Generates higher value of CO_2 emissions

- Speed of the queue calculation
- Emission model
- USA empirical data

Sensitivity Analysis

	Emission of CO_2 (ton)		
	Mini	Small	Big
TM (17days)	48.58	53.85	41.88
TM (1 day)	2.86	3.17	2.46

The results obtained are sensitive to the definition of the area of impact of the work zone.

Results_Rolling Resistance

Model comparison

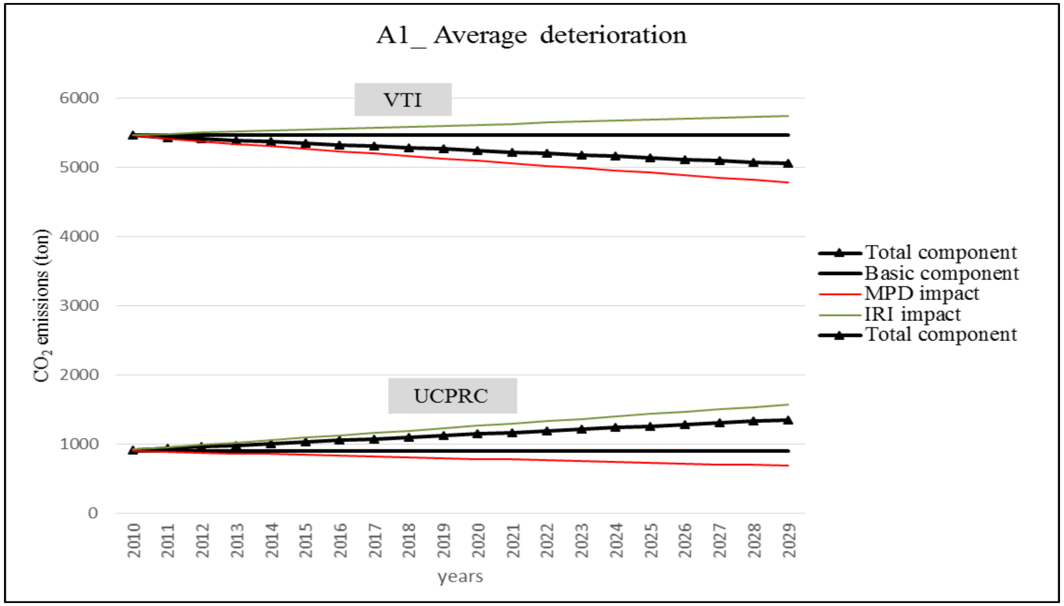
A1			
Model	Emission of CO_2 (ton)		
	Basic	Deterioration	Total
VTI	109344	-4205	105139
UCPRC	18058	4586	22645

Regardless of the deterioration in the IRI and MPD over the analysis period, the two models return considerably different results

Deterioration term for the VTI model is negative and this means that overall the deterioration in pavement surface properties produces a reduction of the vehicle tailpipe CO_2 emissions over the years

Results_Rolling Resistance

Sensitivity analysis



VTI MODEL → MPD has greater impact

UCPRC MODEL → IRI has greater impact

For case studies where the IRI tends to increase and the MPD tends to decrease, the VTI model gives a negative value for the deterioration component, because the MPD term decreases faster than the IRI term increases.

Conclusions

The methodological assumptions and the models chosen for a pavement LCA, in terms of traffic delay due to a maintenance work zone and Rolling Resistance model and pavement condition deterioration, significantly affect the results

TRAFFIC DELAY

Further research is necessary in this area to understand if it is possible to standardize this element and the type of traffic model required for a specific LCA study.

ROLLING RESISTANCE

Site specific elements and methodological choices affect the development of the models, meaning they are not suitable for all geographical locations. In the UK, pavement deterioration models and rolling resistance models need to be developed.

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Thank you all for your attention!

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