

Headingley Café Scientifique

Use of Life Cycle Assessment (LCA) in Comparing the Environmental Impacts of Commuting

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Speaker

- BEng 2001, MSc 2003, Chang'an University, China
- PhD 2007, Newcastle University, UK
- Research Engineer, Scott Wilson (now AECOM), 2007-2011
- Research Fellow, University of Nottingham, 2011-2012
- Lecturer, Liverpool John Moores University, 2012-2018
- Lecturer - Associate Professor, University of Leeds, 2018-present. Duties include:



❖ **Research and Support**

- Life cycle assessment, pavement evaluation and recycling, road safety
- Deputy Director of Postgraduate Research (PGR) Studies

❖ **Teaching and Support**

- Highway Engineering, Maintenance of Pavements, Transport Integrated Project
- Programme Leader, *MSc Transport Planning and Engineering*
- Programme Director, *BEng Civil Engineering with Transport*

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1. Introduction to environmental Life Cycle Assessment (LCA)

- Background
- Method framework

2. Case studies

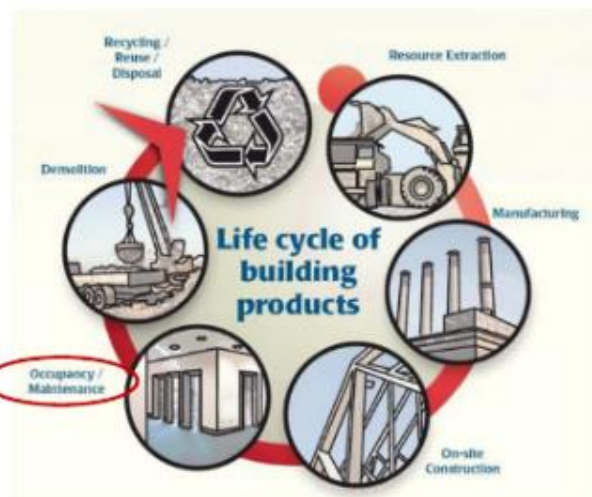
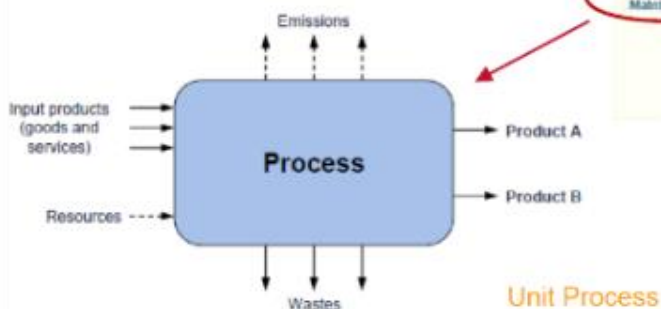
- E-bike and electric vehicles for commuting
- Other uses in road, rail, energy, structures, etc.

3. Resources, Opportunities and Challenges

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Background

“...the process of evaluating the effects that a product has on the environment over the entire period of its life cycle...extraction and processing; manufacture; transport and distribution; use, re-use and maintenance; recycling and final disposal.”

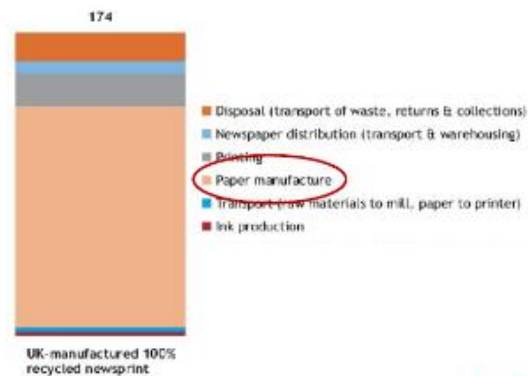


Cradle-to-Grave Analysis

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For product development, it is to identify the high impact process and prioritize for reduction.

Figure 10: Carbon footprint of the Dolly Mirror
g CO₂ per final newspaper sold



Source: Carbon Trust 2006



- Know the big picture of construction

Benefit 1: avoid overlooking the high impact area

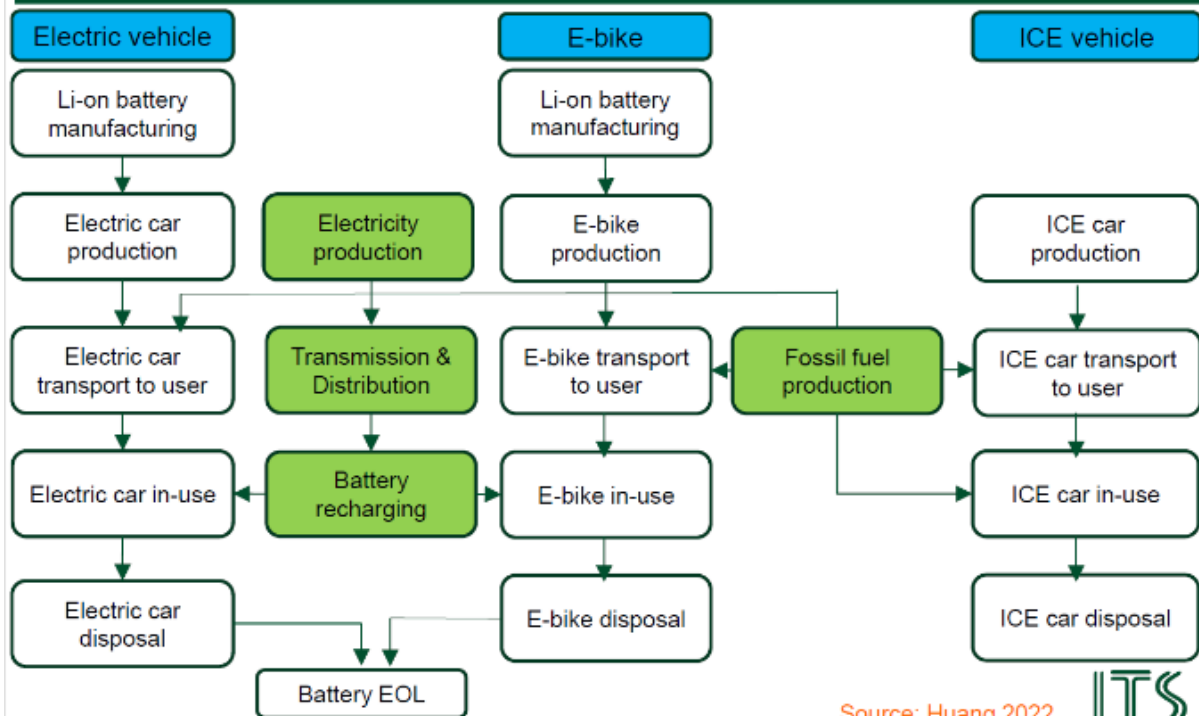
Sub-Sector	MtCO ₂	% of total
Design	1.3	0.5%
Manufacture	45.2	15%
Distribution	2.8	1%
Operations on-site	2.6	1%
In Use	246.4	83%
Refurb/Demolition	1.3	0.4%
Total	298.4	100%

Source: Department for Business Innovation and Skills 2010



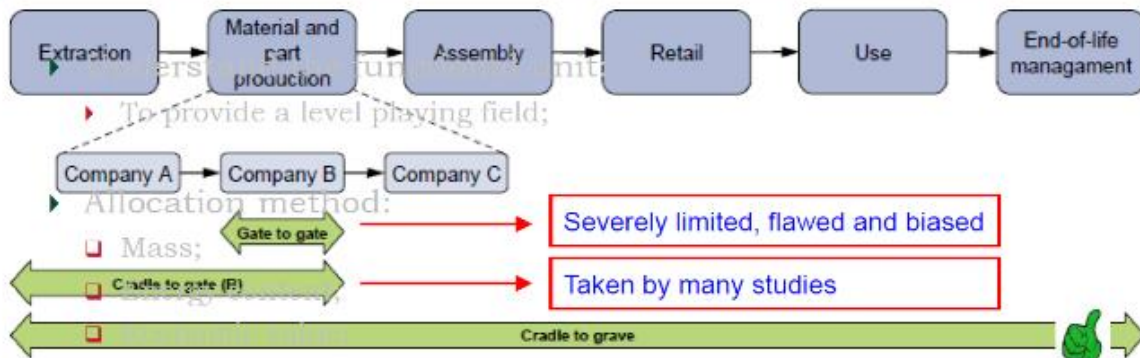
Case Study - System Boundary

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LCA phase 1 – System Boundary

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Source: ILCD 2010

System boundary:

- ☐ Gate to gate;
- ☐ Cradle to gate;
- ☐ Cradle to grave;



How to deal with uncertainty?



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- Understand the functional unit:

- ☐ To provide a level playing field;

800ml ≠ 500ml



- Allocation method:

- ☐ Mass;
- ☐ Energy content;
- ☐ Economic value;

Consider product durability



- System boundary:

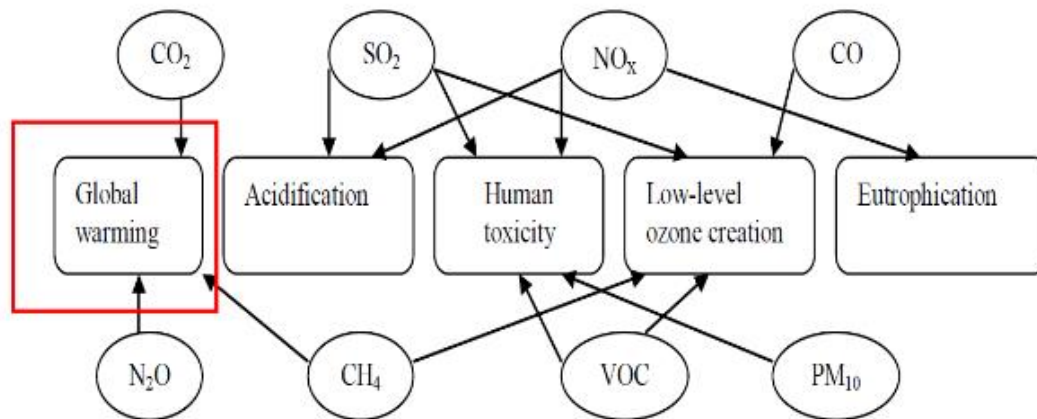
- ☐ Gate to gate;
- ☐ Cradle to gate;
- ☐ Cradle to grave;

Consider supply chain



Production of 1 tonne of bitumen	Unit	Crude oil extraction	Transport	Refinery	Storage	Total
Raw material						
Crude oil	kg	1000				1000
Consumption of energy resources						
Natural gas	kg	18.9	0.4	0.58	0.19	20.1
Crude oil	kg	17.5	9.3	11.9	2.2	40.9
Coal	kg		0.21	0.49	0.33	1.03
Uranium	kg		0.00001	0.00003	0.00002	0.0001
Consumption of non energy resources						
Water	l		48	72	24	143
Emissions to air						
CO ₂	g	99,135	30,078	37,200	7,831	174,244
SO ₂	g	290	334	130	27	781
NO _x	g	270	436	52	11	770
CO	g	524	70	16	3	613
CH ₄	g	548	16	25	6	595
Hydrocarbon	g	0.015	4.6	3.5	38.7	46.8
NM VOC	g	297	15	15	3	331
Particulates	g	132.6	12.7	12.6	3.4	161.2
Emissions to water						
Chemical Oxygen Demand	g		130	176	30	336
Biological Oxygen Demand	g		128	166	30	324
Suspended solids	g		9.4	16.4	4.1	30.0
Hydrocarbon	g	6.9	40.9	52.5	9.5	109.8
Phosphorous compounds	g		2.52	6.77	4.79	14.1
Nitrogen compounds	g		0.95	4.40	1.51	6.86
Sulphur compounds	g		63.2	165.9	119.0	348.1
Emissions to soil						
Hydrocarbon (oils)	g	8.1	42.6	54.9	10.0	116

Source: Eurobitume 2011



Source: IPCC 2007

GHGs	CO2	CH4	N2O	HFCs	PFCs	SF6
CO2 - eq	1	25	298	12-12,000	5,700-11,900	22,200

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Impact category		Units	Design A	Design B
Depletion of minerals	Quarried products	Tonne	286.25	154.75
	Bitumen	Tonne	6.92	7.92
Energy consumption		GJ	121.16	59.48
Global warming potential		kg CO ₂ -eq. (100yrs)	8.91E+03	4.41E+03
Acidification		kg SO ₂ -eq.	26.00	13.10
Low-level ozone creation		kg C ₂ H ₄ -eq.	2.66	2.86
Eutrophication		kg PO ₄ -eq.	1.84	0.91
Human toxicity		kg 1,4-dichlorobenzene-eq	10.76	10.82
Solid waste		Tonne	303.17	161.53

Benefit 2: avoid trading off one impact with another

Source: Huang 2007

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Case Study - Background

1. L-category vehicles – lighter, greener?

2. Electric L-category vehicles

3. Questions remained for vehicle LCA

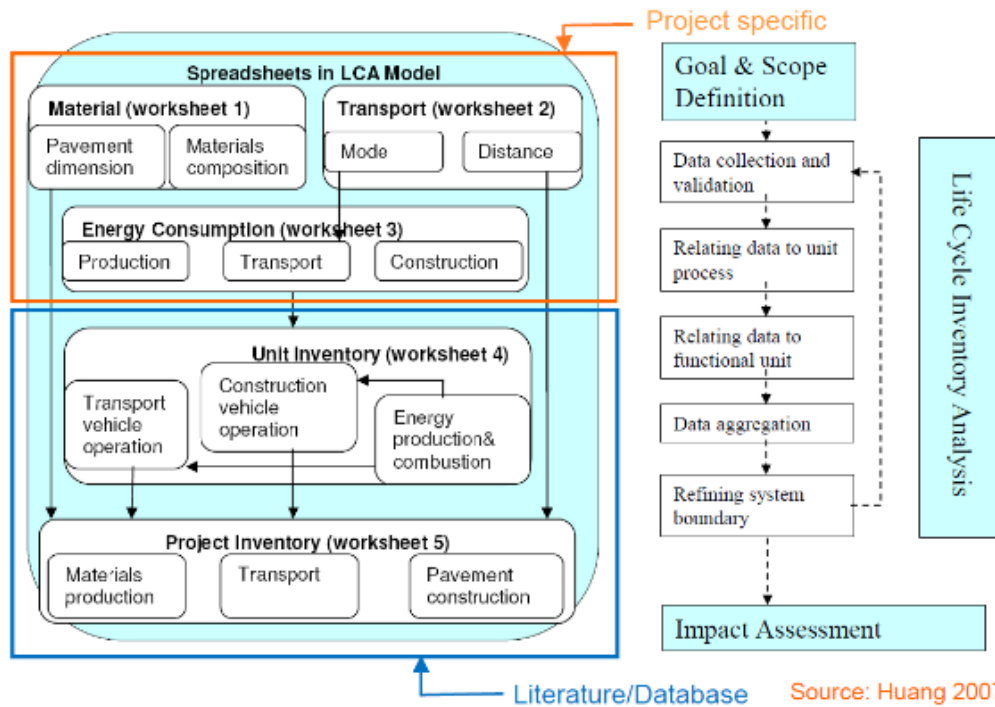
- Non-exhaust (e.g. brake and wear) emissions
- Noise impacts



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Case Study - Model and Data (example)

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Case Study - Data

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- ❑ LCA models/databases, e.g. GREET, SimaPro
- ❑ Literature data, e.g. UK DEFRA
- ❑ Horizon project data, e.g. ELVITEN

Department for Environment Food & Rural Affairs

GREET
LIFE-CYCLE MODEL



ELVITEN



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The screenshot shows a spreadsheet with columns for various LCA parameters. The first column lists categories like 'Construction', 'Transport', and 'Energy'. The second column lists specific processes like 'Cement', 'Concrete', 'Steel', etc. The third column lists units like 'kg', 'm³', 'MJ'. The fourth column lists values. The fifth column lists impact factors like 'CO2e', 'CH4e', 'N2Oe', etc. The sixth column lists impact scores like 'Global Warming Potential', 'Acid Equivalency Potential', etc. The seventh column lists impact scores like 'Global Warming Potential', 'Acid Equivalency Potential', etc. The eighth column lists impact scores like 'Global Warming Potential', 'Acid Equivalency Potential', etc. The ninth column lists impact scores like 'Global Warming Potential', 'Acid Equivalency Potential', etc. The tenth column lists impact scores like 'Global Warming Potential', 'Acid Equivalency Potential', etc. The eleventh column lists impact scores like 'Global Warming Potential', 'Acid Equivalency Potential', etc. The twelfth column lists impact scores like 'Global Warming Potential', 'Acid Equivalency Potential', etc. The thirteenth column lists impact scores like 'Global Warming Potential', 'Acid Equivalency Potential', etc. The fourteenth column lists impact scores like 'Global Warming Potential', 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Source: Huang 2022

Case Study - Results

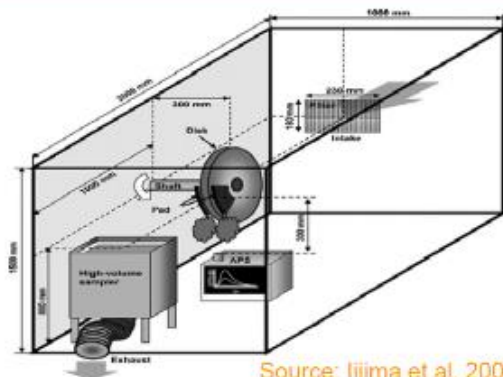
1. Electrification reduced some, while increased other, impacts
2. Key data/assumptions are important
 - ❖ Electricity generation mix
 - ❖ Vehicle energy efficiency
 - ❖ Battery supply chain and end-of-life (EOL)
3. Non-exhaust emissions had significant health impacts

	ICEV	BEV	E-Bike
CO ₂ eq.	1,792.624	733.802	167.325
SO ₂ eq.	1.585	3.012	1.175
DALY	3.924	7.231	2.197
1,4-dichlorobenzene eq.	1.779	3.665	1.430

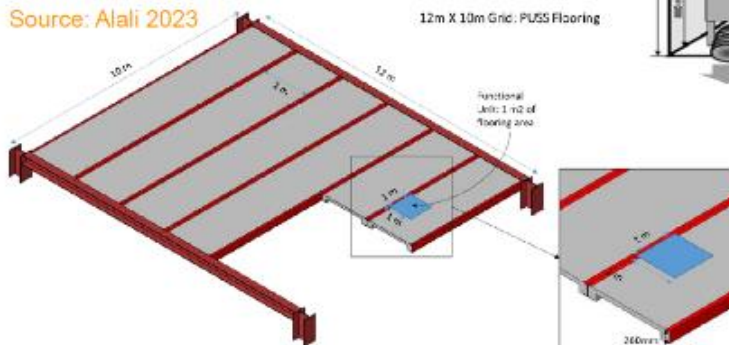


Ongoing doctoral projects

Brake rotor emissions



Source: Alali 2023

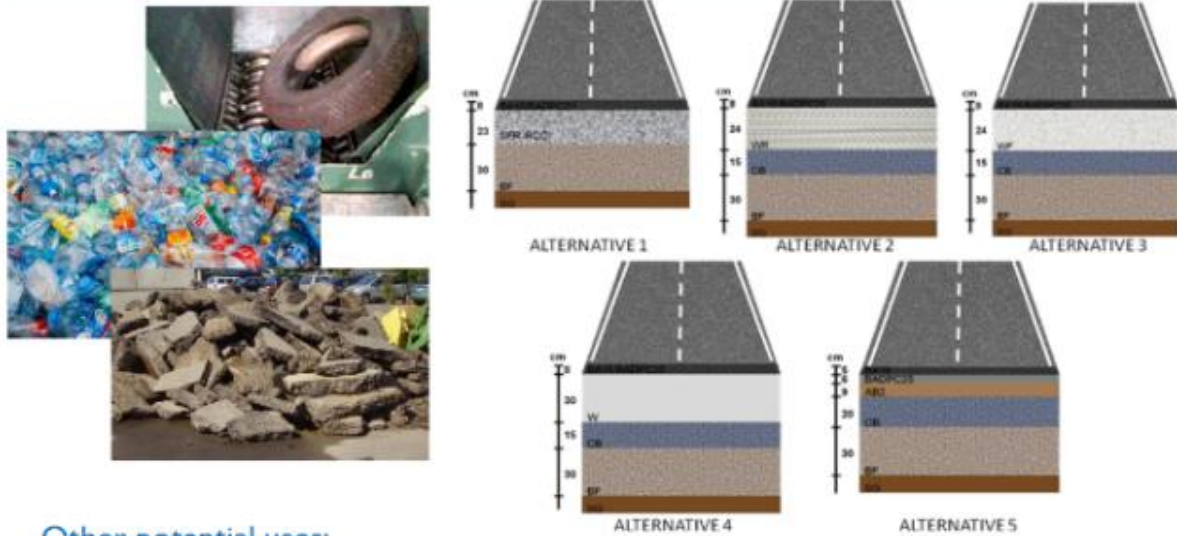


Lightweight flooring in high-rise building

Source: Iijima et al. 2008

LCA in road

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Other potential uses:

- ☐ Use of recycled materials;
- ☐ Mix type (e.g. cold, warm, hot);
- ☐ Recycling method (e.g. in-plant, in-situ);
- ☐ Asphalt vs. Concrete;

Benefit 3: help to make informed decision

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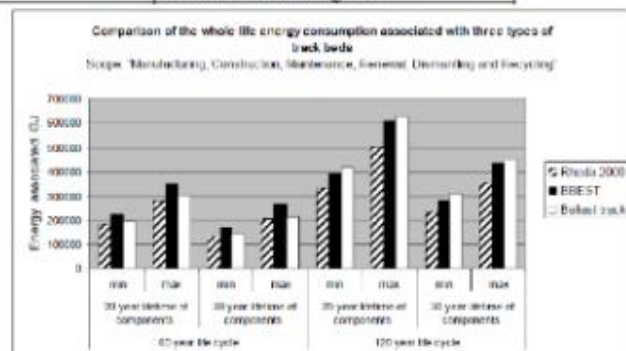
LCA in Rail

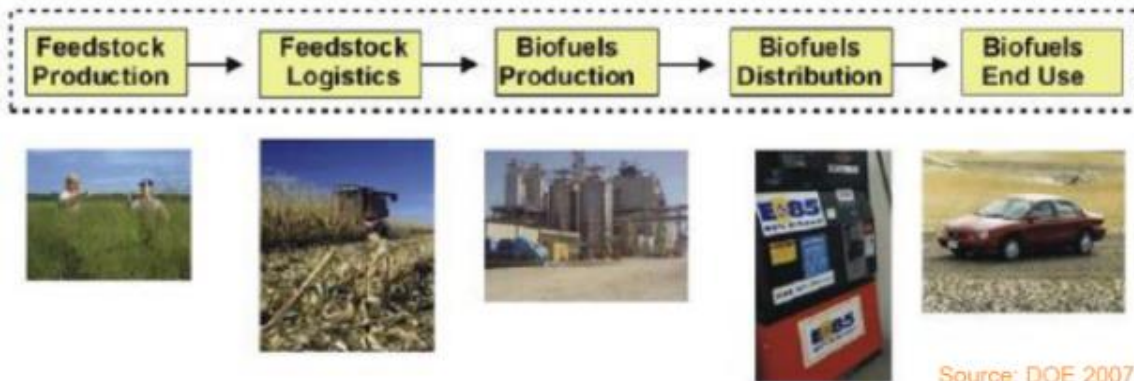
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Ballast	Rheda 2000	BBEST
		
Components	Components	Components
CEN60-E1 rail	CEN60-E1 Rail	BB14072 rail
G44 sleepers at 650 mm centres	sleeper cast in at 650mm centres	reinforced concrete
300 mm ballast depth	fastening: Vossloh 300-1	glass fibre shell
Pandrol fastclip fastening	rubber rail pad	resilient pad and rubber seal
Pandrol rubber rail pad No.8854	C40 concrete	C40 concrete and grout

• LCA of rail tracks

Source: Kiani 2008





- ✓ 'Carbon neutral';
- ✓ Less emissions on combustion, compared with fossil fuels;
- ✓ But think about life cycle;
- ✓ Think about change in land use;

Benefit 4: avoid shifting the problem elsewhere

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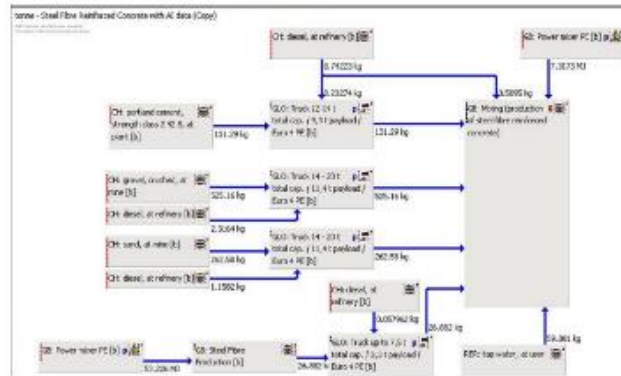
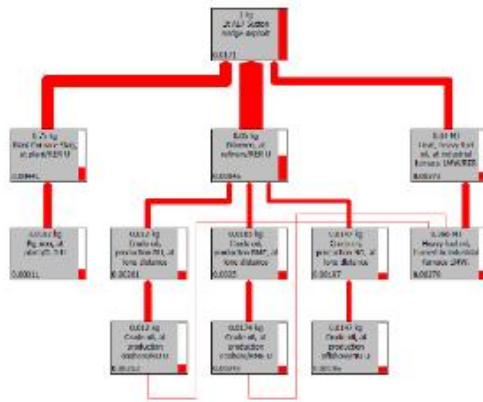
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- Commercial LCA software are available, e.g. SimaPro

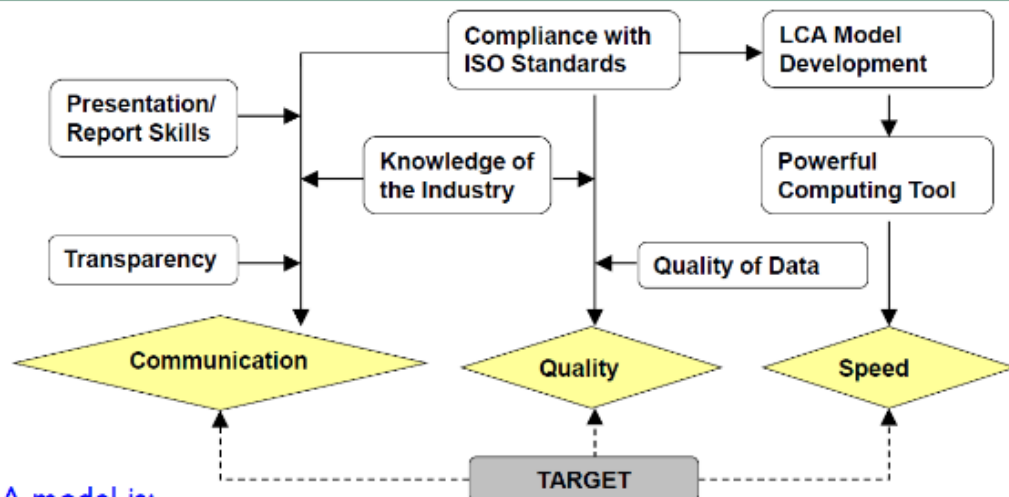


- ✓ Built-in inventory databases;
- ✓ Accuracy and speed;
- ✓ Share modelling and data library with project partners;

- ✗ Licence fee;
- ✗ Investment in staff training;



LCA – What makes a good LCA model



A good LCA model is:

- Industry recognised (methodology, datasets);
- Populated with current and reliable data;
- Transparent with system boundary, functional unit, allocation, etc.;
- Forward compatible for data update and formulae revision;

Source: Huang 2007



Summary of benefits:

- ☐ Avoid overlooking hot-spot areas
- ☐ Avoid trading off one impact with another, possibly worse, impact
- ☐ Avoid shifting the problem elsewhere
- ☐ Help to make informed decision, e.g. asset management

Some weaknesses:

- ☐ Time consuming, needs subject knowledge, need good quality data
- ☐ No sensitivity to time or location
- ☐ No economic or social perspectives

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Publications

- **Huang Y**, Jiang L, Chen H, Dave K, Parry T. 2022. Comparative life cycle assessment of electric bikes for commuting in the UK. *Transportation Research Part D: Transport and Environment*. 105
- Galatioto F, **Huang Y**, Parry T, Bird R, Bell M. 2015. Traffic modelling in system boundary expansion of road pavement life cycle assessment. *Transportation Research Part D: Transport and Environment*. 36, pp. 65-75
- **Huang Y**, Spray A, Parry T. 2013. Sensitivity analysis of methodological choices in road pavement LCA. *The International Journal of Life Cycle Assessment*. 1(13), pp. 93-101
- **Huang Y**, Bird R, Heidrich O. 2009. Development of a life cycle assessment tool for construction and maintenance of asphalt pavements. *Journal of Cleaner Production*. 17(2), pp. 283-296

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