The Centre for Sustainable Road Freight

Structural Optimisation of a Composite Semi-trailer Chassis

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SDC TESCO

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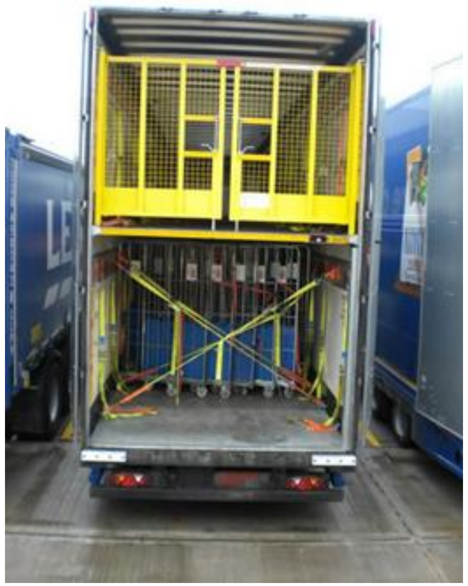
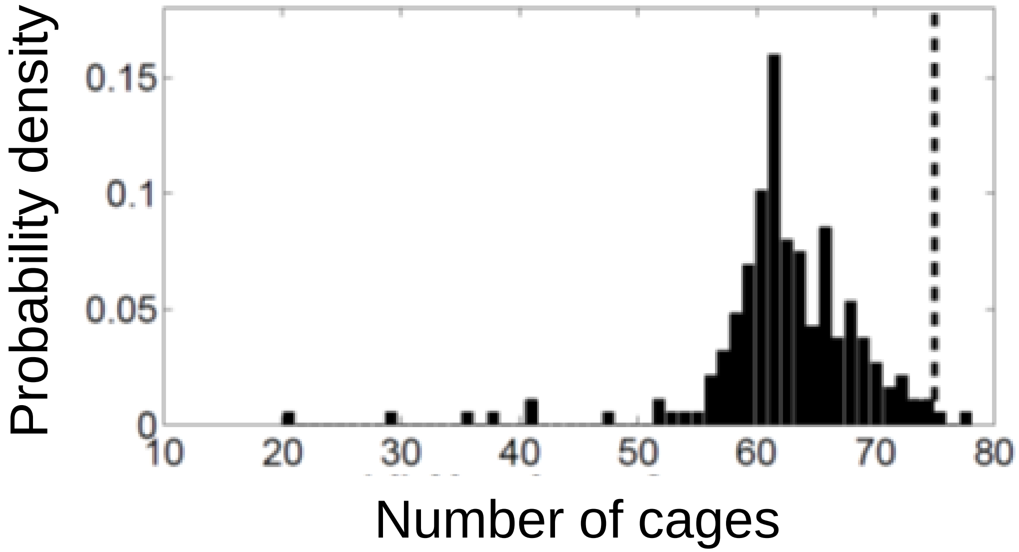
Motivation

- Light-weighting is useful for weight-limited freight operations to increase capacity
- Tesco long-haul ambient double-deck fleet, for example, meet this criterion





Trailer axle weights near the legal limit prevent Tesco filling their double-deckers to the capacity of 75 cages

Background

- Various composite options have been demonstrated, but lack market impact
- Need to combine manufacturers’ R&D plans with user’s needs, driven by business case

13.6m Refrigerated Aldi TTT Trailer
(Carbon fibre/ epoxy monocoque design)

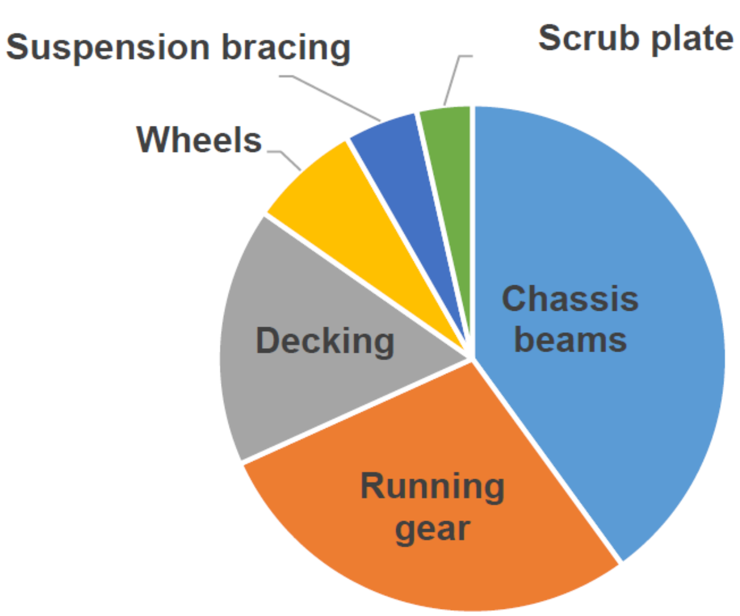
13.6m Phoenixx Trailer (CFRP chassis)

13.6m Composittrailer (GFRP chassis & composite sandwich side walls)

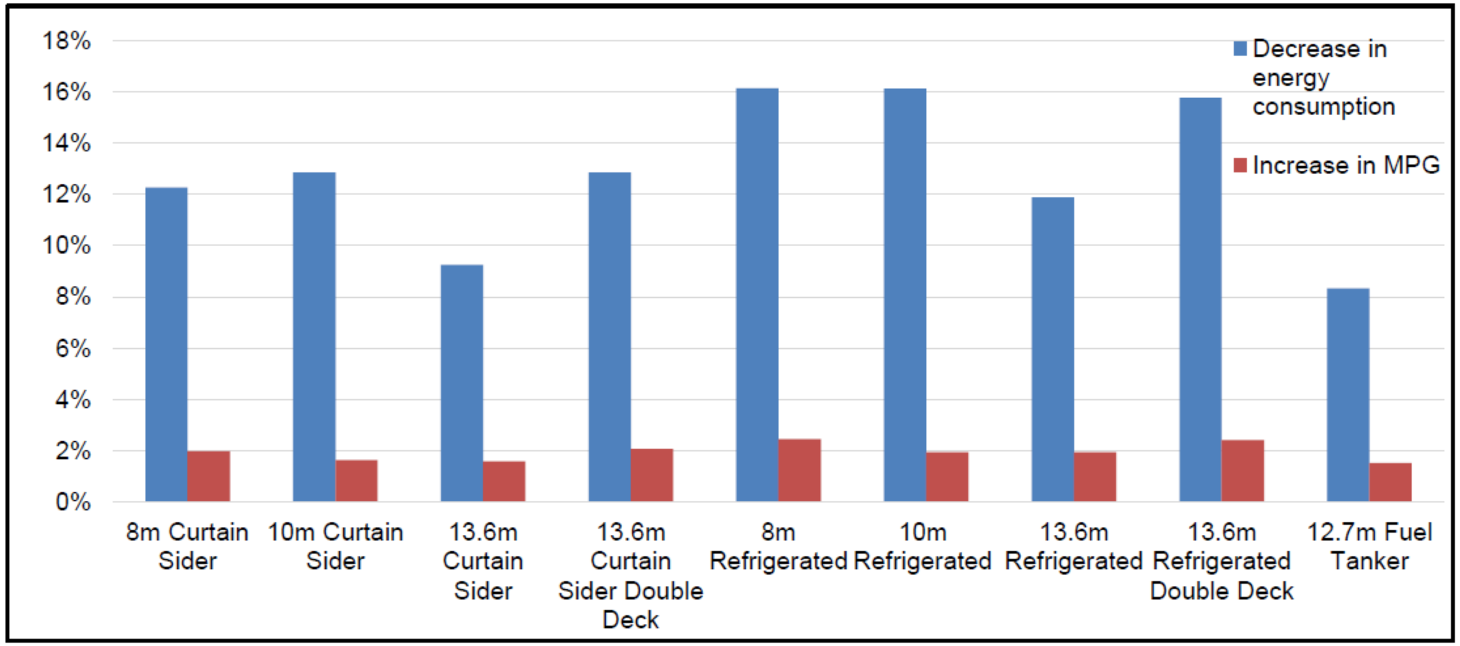
10m ROADLITE Trailer (GFRP chassis)

Background

- Various opportunities to reduce trailer weight
- Significant reductions in CO_2 possible, with extra cargo carried per journey



Typical weight breakdown of a 13.6m flatbed trailer



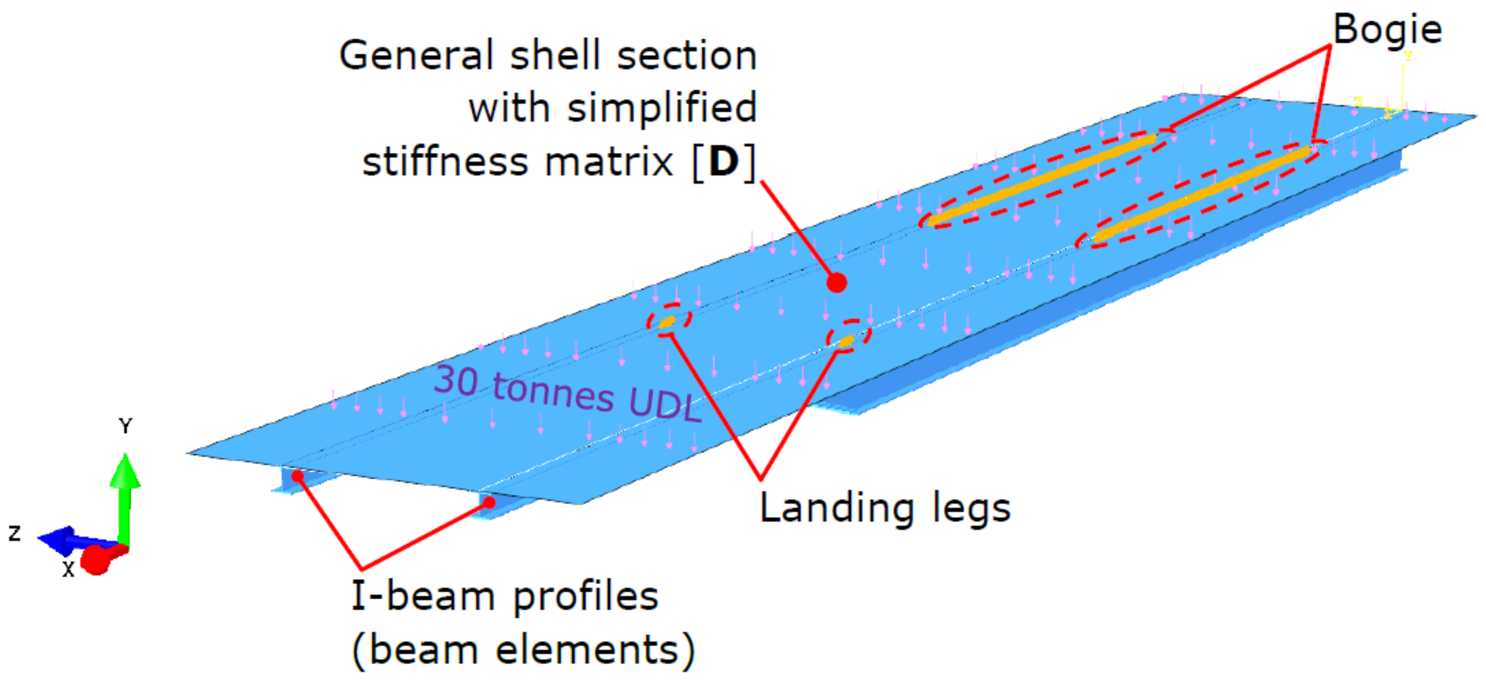
Approximate energy saving for a 30% reduction in trailer weight

Aim

To explore theoretically the potential for trailer weight reduction using different composite options.

Structural concept

- Moulded designs seem to provide a good solution, taking advantage of composite manufacturing routes, but there is a significant barrier to implementation
- As an alternative, develop existing design concept, using main beam with structural decking
- Optimise: (i) material choices, (ii) shape of beams, (iii) decking



Structural variants: preliminary design

Beam materials: steel, aluminium, CFRP, GFRP

Beam geometry

Beam component	**Modelled dimensions (mm)**
Flange thickness	5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60
Flange width	100, 150, 200, 250, 350, 400
Web thickness	2/3 × flange thickness
Beam height – rear	385, 425, 465
Beam height – front	130, 150
Beam height – goose-neck	279

Decking materials: Pultruded GFRP or CFRP-balsa sandwich panel

- stiffness of decking defined by stiffness matrix **D.**

Structural variants: second iteration

Beam materials: CFRP, or hybrid CFRP / GFRP (front / back of trailer)

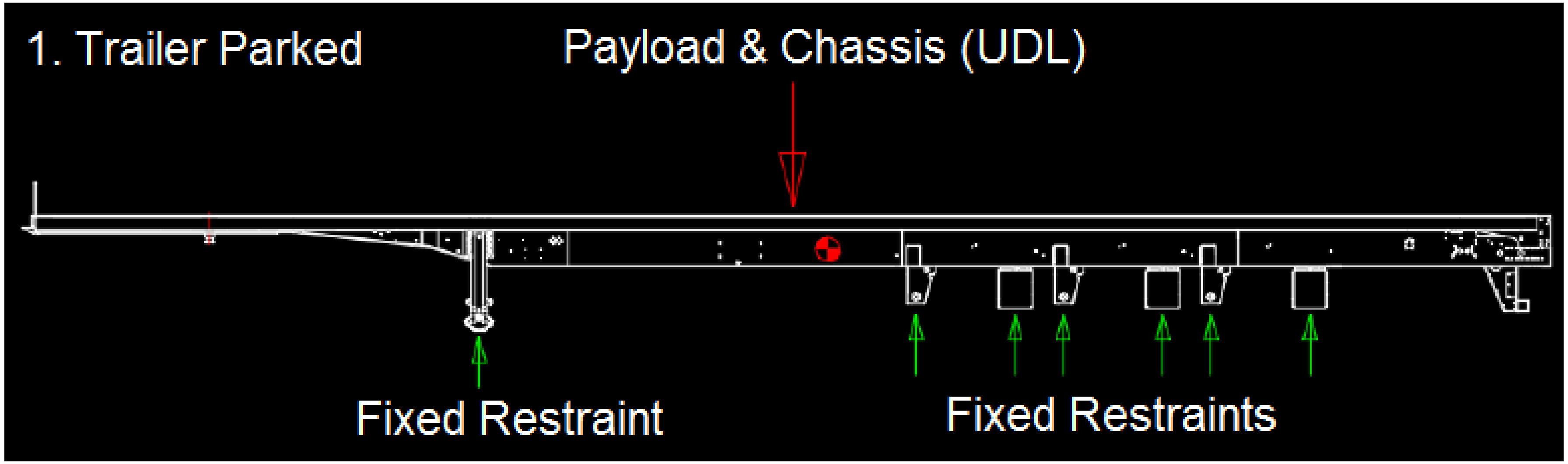
Beam geometry

Beam component	Modelled dimensions (mm)
Rear flange thickness (t_r)	2.5, 5, 7.5, 10, 12.5, 15
Front and goose-neck flange thickness (t_{fr})	5, 10, 15, 20, 25, 30
Rear flange width	150, 250, 350, 450, 550, 650, 750, 850, 950, 1050, 1150, 1250
Front and goose-neck flange width	150, 250, 350, 450, 550, 650, 750, 850, 950, 1050, 1150, 1250
Rear web thickness	2/3 × t_r
Front and goose-neck web thickness	2/3 × t_{fr}

Decking material: Pultruded GFRP

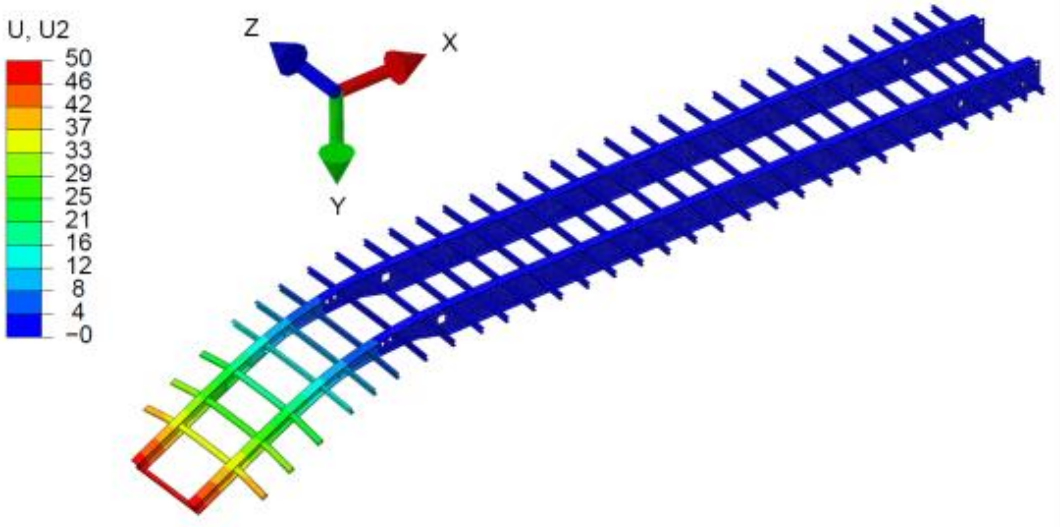
Load cases

- Other studies have investigated various critical load cases
- Here the manufacturer’s critical load cases are used as a benchmark, comparing traditional and composite designs
- Critical load cases of a fully loaded trailer either running on 5th wheel or standing on landing legs

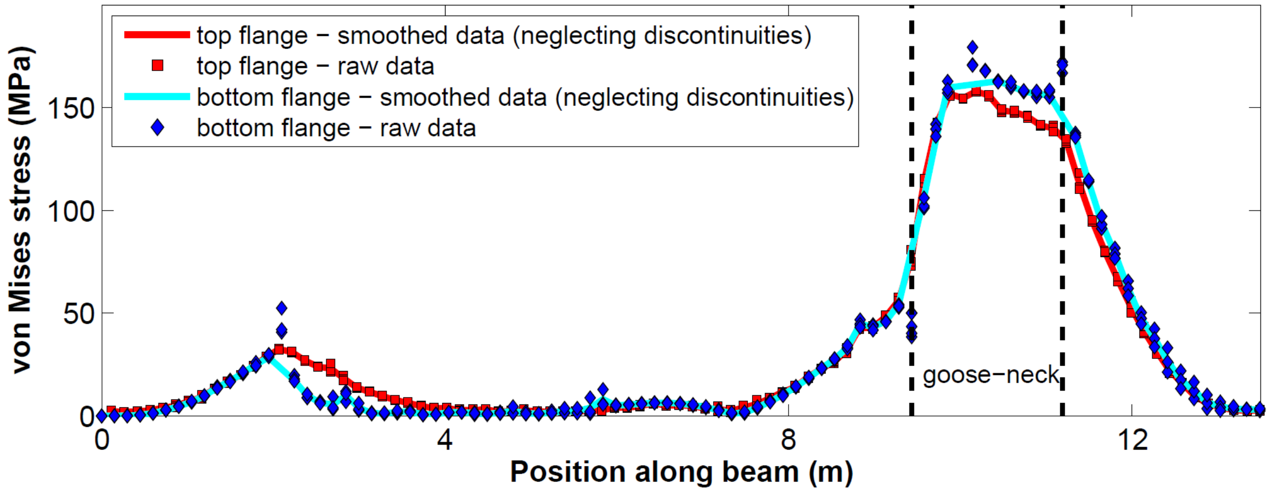


Analysis

- Use Abaqus finite element (FE) software to find the deflections and stresses associated with each candidate design and load case
- Stresses in the beam flanges and decking taken from FE analysis



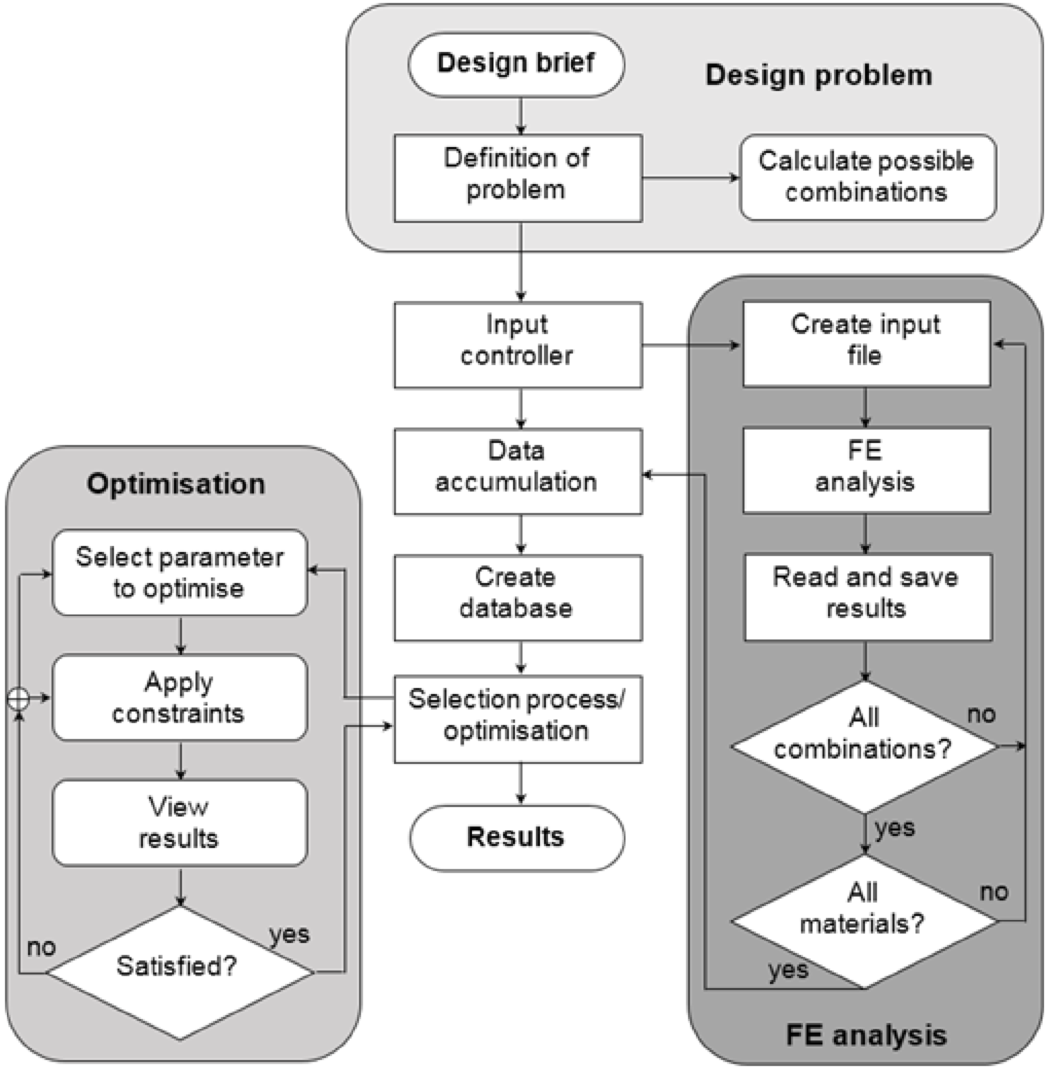
Deflections (in mm) for a parked trailer



Von Mises stress along the top and bottom flanges

Optimisation

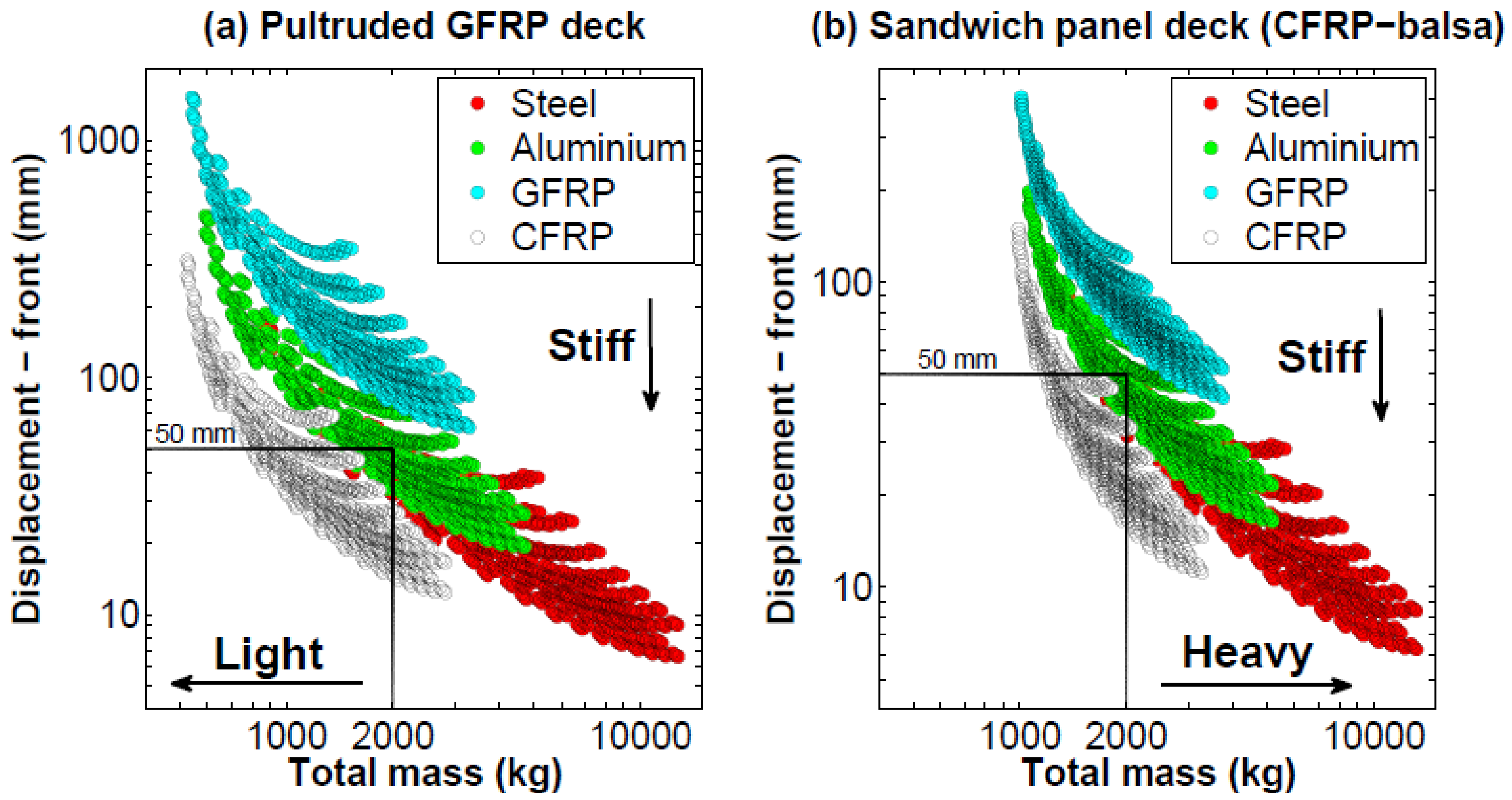
- Use brute-force optimisation approach developed by Monroy Aceves
- Python scripts to manage analysis and data extraction
- Visualisation to examine solutions



Analysis flow chart

Results: preliminary design

Effect of changes in beam design and material with two decking choices



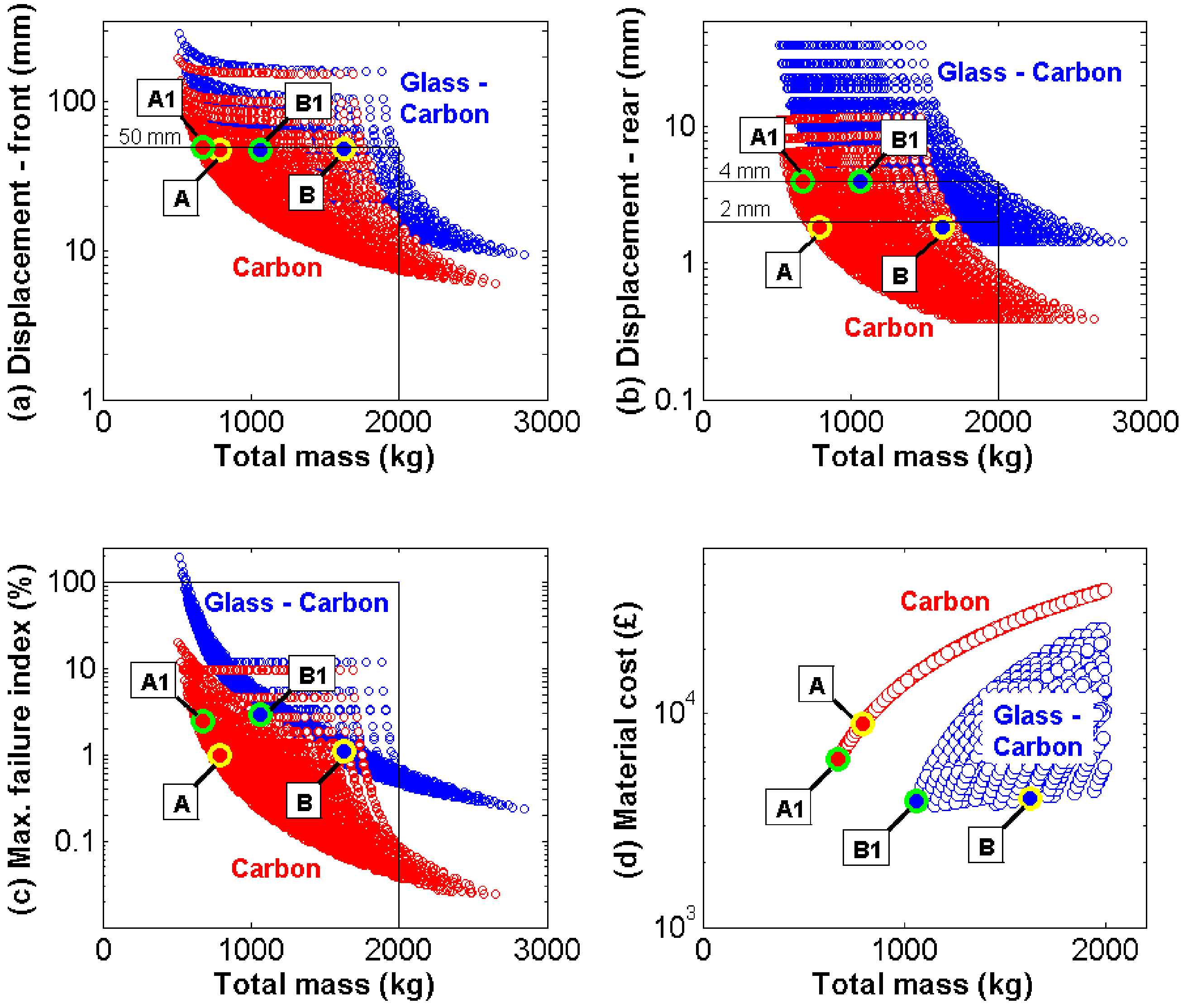
Guidelines of 50 mm deflection and 2000 kg mass are for existing baseline design

- Significant mass reduction possible for CFRP beams
- Stiffer CFRP deck does **not** give significant stiffness performance gain, while being heavier

Results: second iteration

Effect of changes in beam design with pultruded GFRP decking

- Designs are deflection rather than strength limited
- Carbon beams give a very significant weight reduction of 60% (A)
- Relaxing the rear deflection constraint makes glass-carbon beams attractive (B1) with a weight reduction of 47%
- The use of glass in the rear of the trailer brings the material cost down significantly



Guidelines are for existing baseline design

Conclusions

- The design methodology allows for examination of a wide choice of trailer designs
- Stiffer decking does not contribute significantly to improved performance
- Significant weight advantages possible with CFRP
- A hybrid GFRP/CFRP design may provide the best cost-benefit performance
- Need to combine theoretical weight gains with pathways to implementation