Optimising Electric Road Freight Charging Infrastructure for Long-Distance Corridors in Namibia

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Outline

- Rationale
- Existing literature
- Proposed methodology
- Implementation
- Expected contributions

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Why?

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Electrification is central to freight decarbonisation

- Transport accounts for 20% of global greenhouse emissions
- Road freight accounts for 75% of transport emissions worldwide

Therefore, **road freight needs to be electrified**

This requires **strategically placed recharging infrastructure**

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The optimisation problem: where and how should charging stations be installed?

- Where should charging stations be installed?
- How many stations are needed?
- How many chargers are needed at each station?
- Which corridors should be prioritised?
- How do we maintain network coverage whilst controlling cost?

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My research group: TransiT

- The UK's largest research hub dedicated to decarbonising transport using digital twins
- A collaboration of 8 universities and almost 70 industry partners

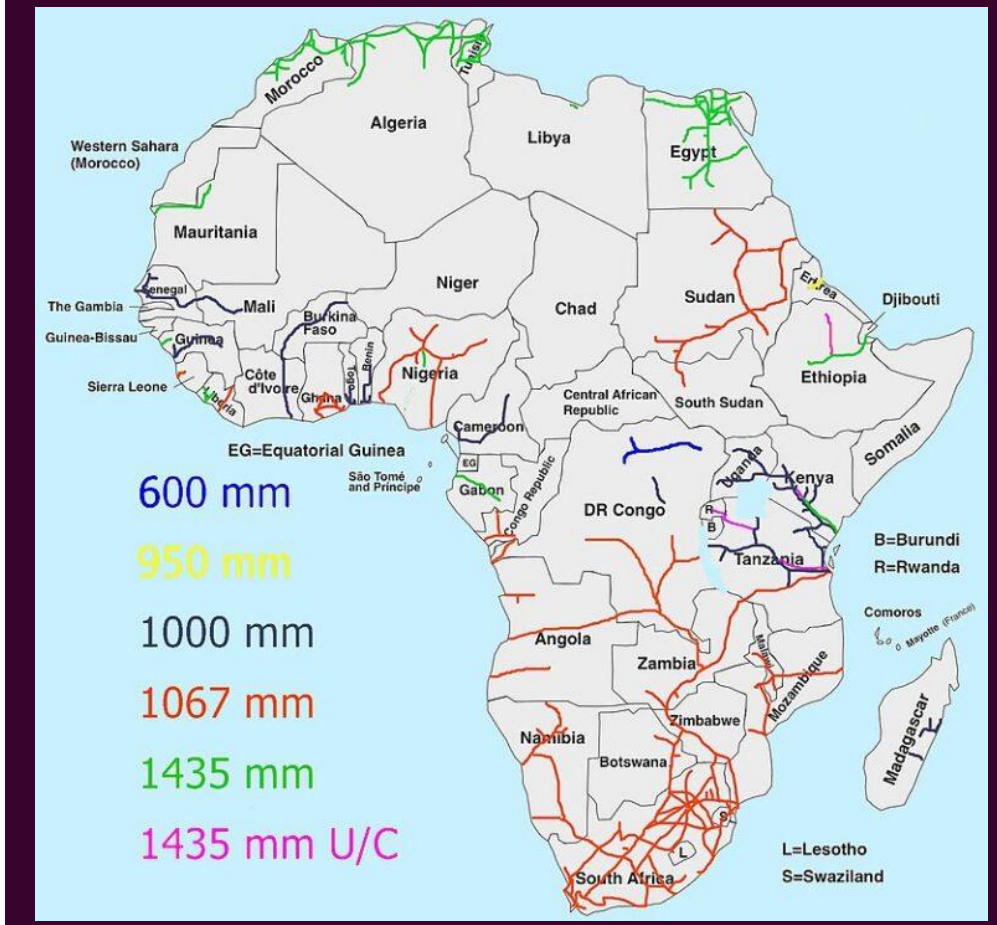
Used Scottish truck data to identify key recharging locations within Scotland



Figure 2 in Towards Zero Emission HGV Infrastructure in Scotland (Greening et al., 2024), Centre for Sustainable Road Freight, Heriot-Watt University, commissioned by Transport Scotland.

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Sub-Saharan African logistics operate under unique constraints



- Freight corridors are vital for regional trade
- Long-distance corridors and cross-border transport networks
- Sparse charging infrastructure
- Current literature focuses on the Global North

Vivid Maps, Mapped: Africa's Transport System. Available at: https://vividmaps.medium.com/mapped-africas-transport-system-32328da1542c

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Namibia is an extreme test case for charging infrastructure design

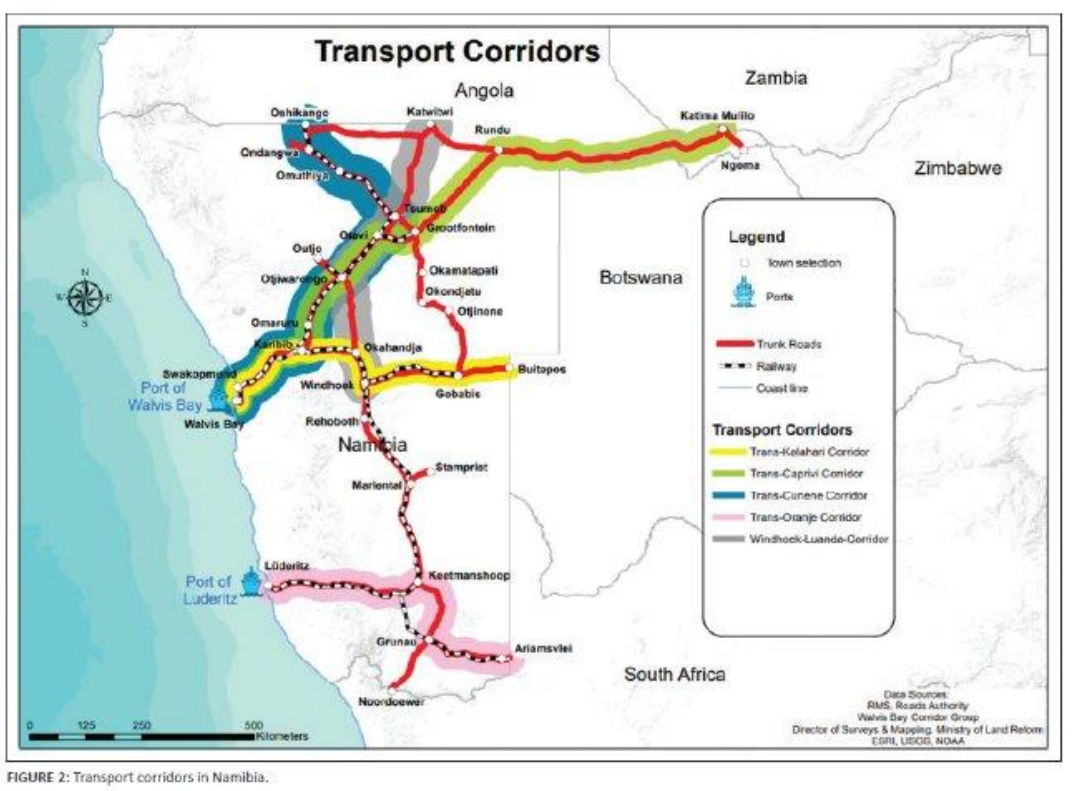


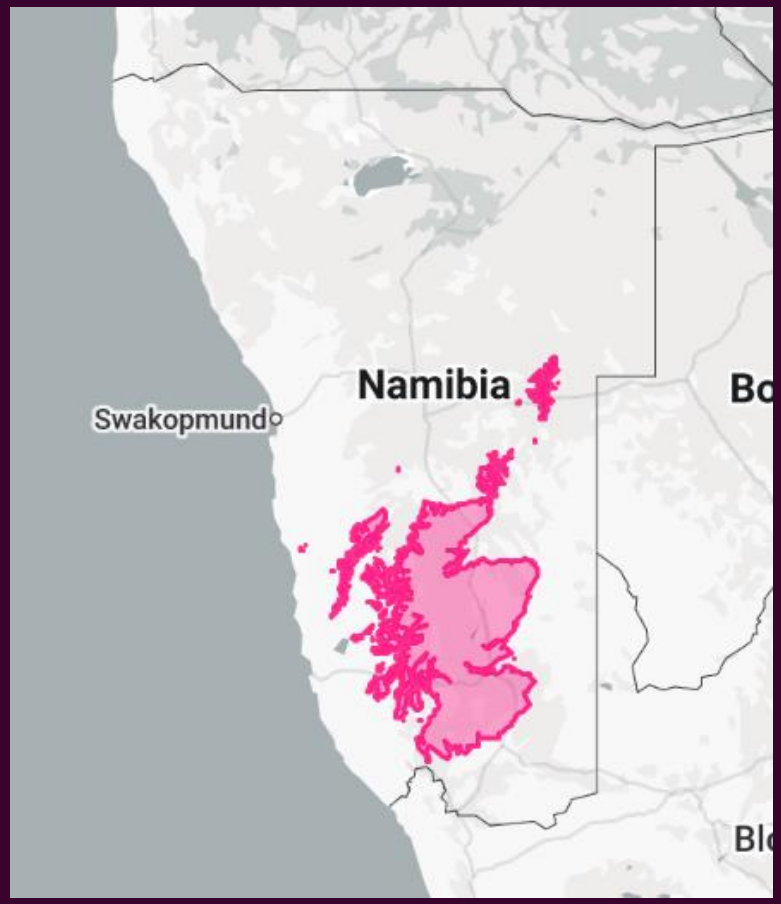
FIGURE 2: Transport corridors in Namibia.

Map of transport corridors in Namibia

Source: RMS. Roads Authority. Walvis Bay Corridor Group. Director of Surveys & Mapping. Ministry of Land Reform.ESRI, USGS,NOAA

- Population of approximately 3 million – one of the most sparsely populated countries
- Extremely large inter-city distances
- Strategic regional transport hub

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The existing literature

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Charging station placement as an optimisation problem

Decision variable:

$$x_j = \begin{cases} 1 & \text{if a charging station is constructed at} \\ & \text{candidate location } j, \\ 0 & \text{otherwise.} \end{cases}$$

Potential objectives:

- Minimise cost
- Maximise coverage
- Maximise demand served

Potential constraints:

- Budget limits
- Vehicle range
- Station capacity
- Electricity network

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Transportation network approaches

Determine:

- Location
- Capacity
- Configuration

Main decision factors:

- Accessibility
- Traffic flows
- Charging demand
- Utilisation
- Costs

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Transportation network approaches

Exact approaches

- Facility location models
- Flow-based models
- Queueing models

Approximate approaches

- Genetic algorithms
- Particle swarm optimisation
- Grey wolf optimisation

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Electricity network approaches

- Charging stations create major issues within local electrical grids
- Main decision factors:
  - Voltage stability
  - Power losses
  - Transformer loading
  - Grid capacity
  - Electrical demand
- Increasing number of hybrid approaches

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There is currently very limited work on electric road freight charging infrastructure

What the current literature studies	What is unexplored
Passenger EV charging	Limited focus on large operational vehicles
Urban environments	Long-distance fleets of vehicles
Global North transportation networks	Different geographical contexts

Key gap: How can existing optimisation methods be adapted to road freight networks operating under geographic constraints?

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Proposed methodology

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Project aims

- To adapt existing charging station placement optimisation approaches to electric road freight
- To compare approaches and identify the ‘best’ methods
- To compare method performance for different geographical contexts

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Proposed research framework

1. Literature review + identification of chosen approaches
2. Data collection
3. Network development
4. Implementation of optimisation approaches
5. Simulation
6. Approach comparison

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Identifying candidate methods

What I know

- Large-scale datasets = approximate approaches
- Complexity of problem = multi-objective

What I don't know

- Genetic algorithm
- Evolutionary algorithm
- Particle swarm optimisation
- Grey wolf
- Simulated annealing
- And many more…

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Data collection

- Traffic count data
- Vehicle telematics data
- Road networks
- Electricity networks (eventually)

Desired: several datasets representing different geographical topologies

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Implementing the chosen optimisation methods to model freight

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Transitioning from passenger EV models to road freight models

Passenger EVs	What is unexplored
Short urban trips	Long-distance corridors
Flexible charging	**Operational schedules**
Small batteries	Large batteries
Home/work charging	Depot and public high-power charging
Individual driving behaviour	**Fleet operation behaviour**

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The optimisation problem for electric freight charging

Decision variables

- Charging station locations
- Number of charging stations
- Number of chargers per station

Objectives

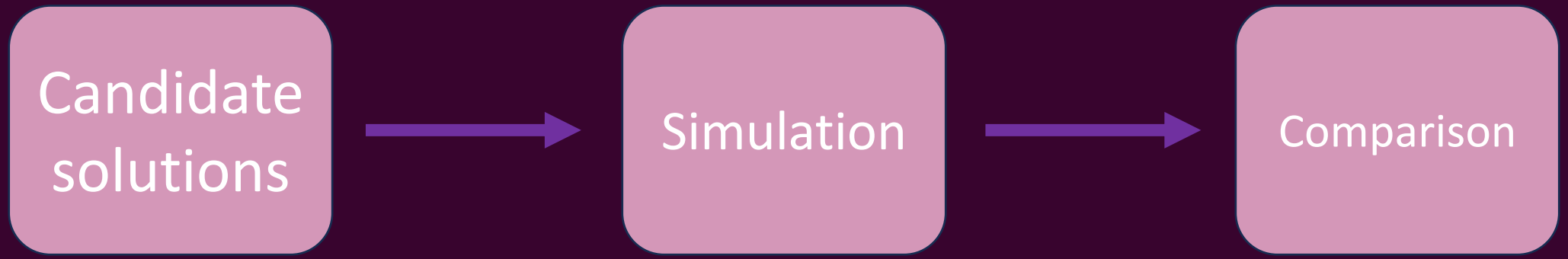
- **Minimise operational cost**
- **Minimise delays**
- Minimise infrastructure cost
- Minimise strain on electrical network

Constraints

- Vehicle range
- **Delivery schedules**
- **Driver-hour regulations**
- Operational costs

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Evaluation (down the line)



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Expected contributions

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- A data-driven combinatorial optimisation framework for electric freight charging infrastructure
- Insights into infrastructure planning for the Global North vs Global South
- A geographically-realistic decision-support tool to aid freight decarbonisation policies and investment

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