Framework for Strategic Hydrogen Refuelling Infrastructure Analyses

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Research Overview

Challenge The deployment of hydrogen refuelling infrastructure in corridors for Heavy Goods Vehicles (HGVs)

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- What are the refuelling demands for HGVs along the corridors?

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- What are the refuelling demands for HGVs along the corridors?
- What is the minimum number of hydrogen refuelling points required to serve the refuelling demand?
- What are the geographic locations and capacities of the hydrogen refuelling points?
- What is the best hydrogen dispense and delivery model to follow?

Research Aim

Aim Analyse strategic corridors to determine and recommend hydrogen refuelling infrastructure for effective deployment

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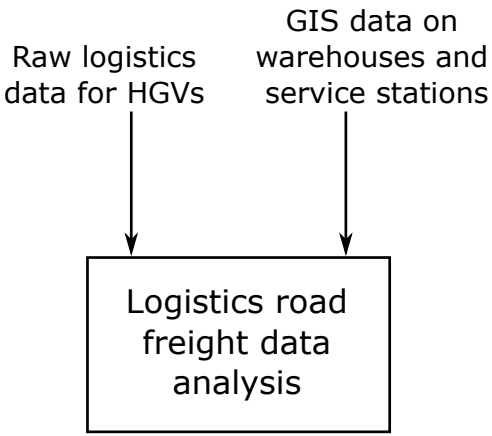
- Translate HGV diesel demand to an HGV hydrogen demand
- Organic growth of diesel refuelling network over time
- Determine optimal network for hydrogen refuelling infrastructure
- Outcome
  - Optimal number of refuelling points
  - Location, capacity and type of refuelling points
  - Strategic and operational configurations of hydrogen supply chain
  - Economic, environmental and risk impact

Research Methodology



Research Methodology

Input data: GIS data on warehouses

- 1 765 records with seven features, cleaned and filtered to 626 records

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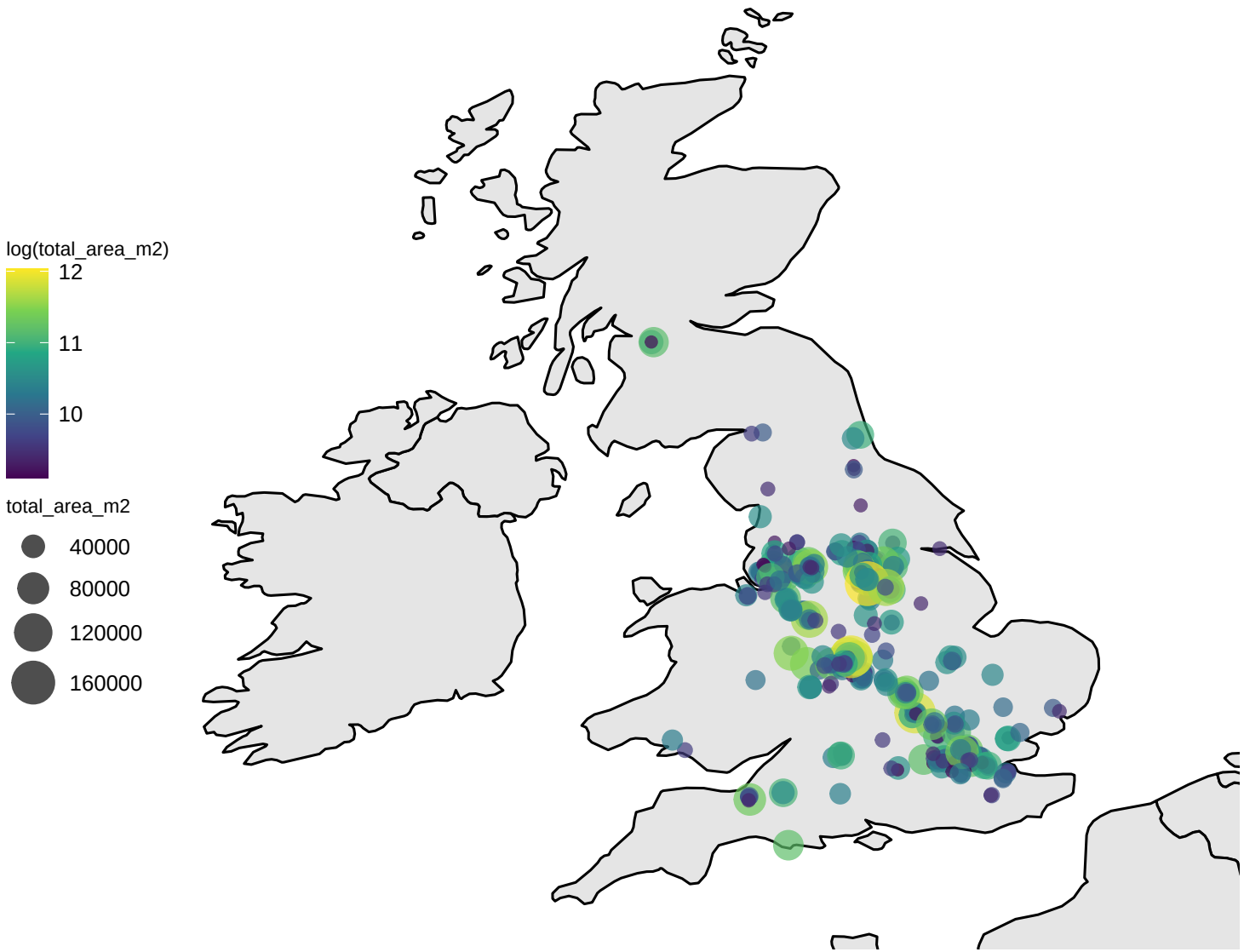
- 382 records (total area range 9 014–168 172 m^2, $\mu = 30\,188$ m^2)

Research Methodology



Research Methodology

Input data: GIS data on service stations

- 291 records with six features, cleaned and filtered to 111 records

	`Station Name`	Address	Latitude	Longitude	StationType	Brand
	<chr>	<chr>	<dbl>	<dbl>	<chr>	<chr>
1	ESSO EG KINMEL PARK EAST	"TEBAY M6 NORTH, CUMBRIA, PENRITH"	54.4	-2.61	hgv	Esso
2	ESSO EG KINMEL PARK WEST	"A55 EXPRESSWAY- WESTBOUND, BODELWYDDAN"	53.3	-3.51	hgv	Esso
3	ESSO EG WYLFA	"CHESTER ROAD, MOLD"	53.2	-3.13	hgv	Esso
4	ESSO QUEENSFERRY	"CHESTER ROAD EAST, QUEENSFERRY\xa0"	53.2	-3.02	hgv	Esso
5	ESSO EG BANGOR	"JUNCTION A5/55 EXPRESSWAY, LLANDEGA, BANGOR~	53.2	-4.11	hgv	Esso
6	ESSO RONTEC RUABON	"RUABON BY PASS, WREXHAM\xa0"	53.0	-3.03	hgv	Esso
7	ESSO WIDNES	"MOOR LANE, WIDNES\xa0"	53.4	-2.74	hgv	Esso
8	ESSO EG Larkhill	"QUEENS DRIVE, LIVERPOOL\xa0"	53.4	-2.92	hgv	Esso
9	ESSO EG Sugarbrook	"EAST LANCASHIRE ROAD, LIVERPOOL\xa0"	NA	NA	hgv	Esso
10	ESSO EG WHITCHURCH	"WREXHAM ROAD, WHITCHURCH\xa0"	53.0	-2.71	hgv	Esso

... with 101 more rows

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... with 101 more rows

- Key features: Type (only HGV), latitude, longitude

Research Methodology

Research Methodology

Input data: Raw logistics data for HGVs

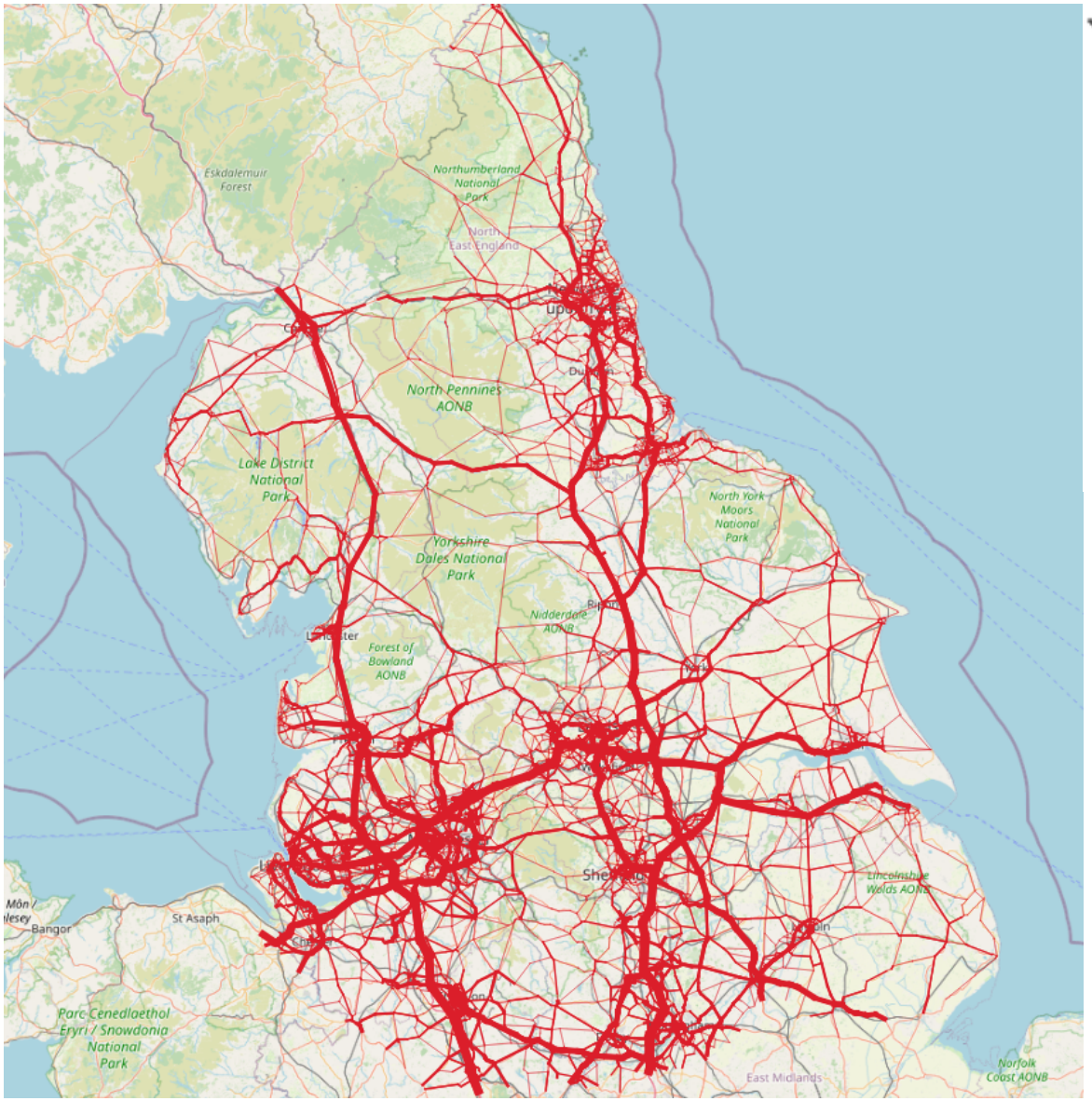
- Various datasets from research partners
- Freight data for 2018 per road link
  - Start and end node
  - Hourly HGV actual flow
  - Volume to capacity ratio (measure of congestion)
  - Net speed
  - Queues (delays/traffic disruption)
  - Cruise time
  - Distance
- Journey data
- Annual HGV tonnage by commodity
- Predicted freight data for 2050

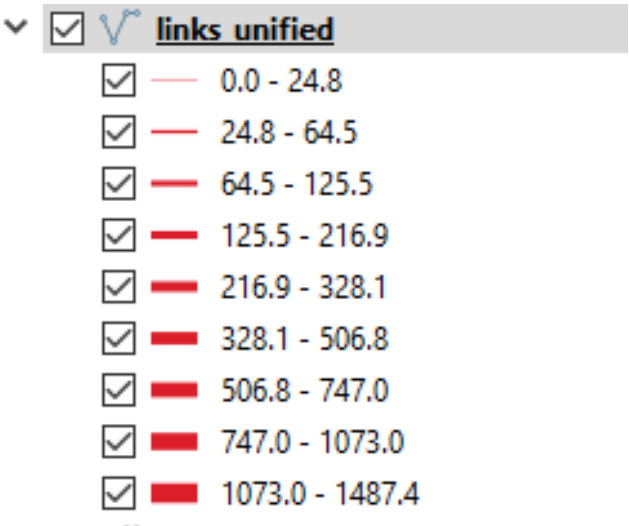
Research Methodology

Analysis

1. Analyse HGV logistics data for modelling HGVs movement in agent-based environment

Research Methodology





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Consider a total energy demand ϵ_{total} with the total energy demand fulfilled by warehouses and service stations denoted as ϵ_W and ϵ_S, respectively. Given that warehouses account for a portion of α of the total energy demand fulfilment, then

$$\epsilon_W = \alpha\epsilon_{total} \tag{1}$$

$$\epsilon_S = (1-\alpha)\epsilon_{total}. \tag{2}$$

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- Allocate energy demand fulfilment per warehouse proportionally to the warehouse's total area

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Given that there are N warehouses in the system and that the size (total area) of warehouse i is denoted as λ_i, the energy demand fulfilled by warehouse i is

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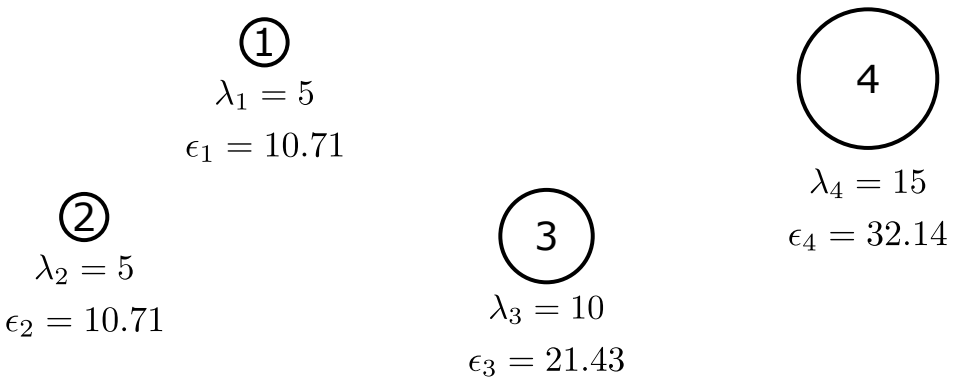
$$\epsilon_{total} = 100$$
$$\alpha = 0.75$$



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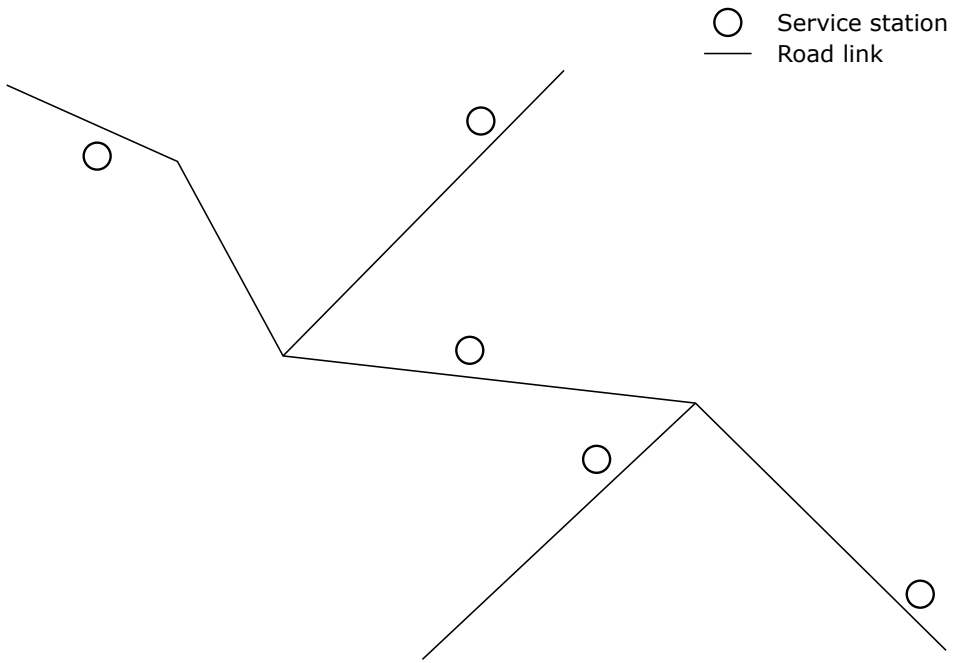

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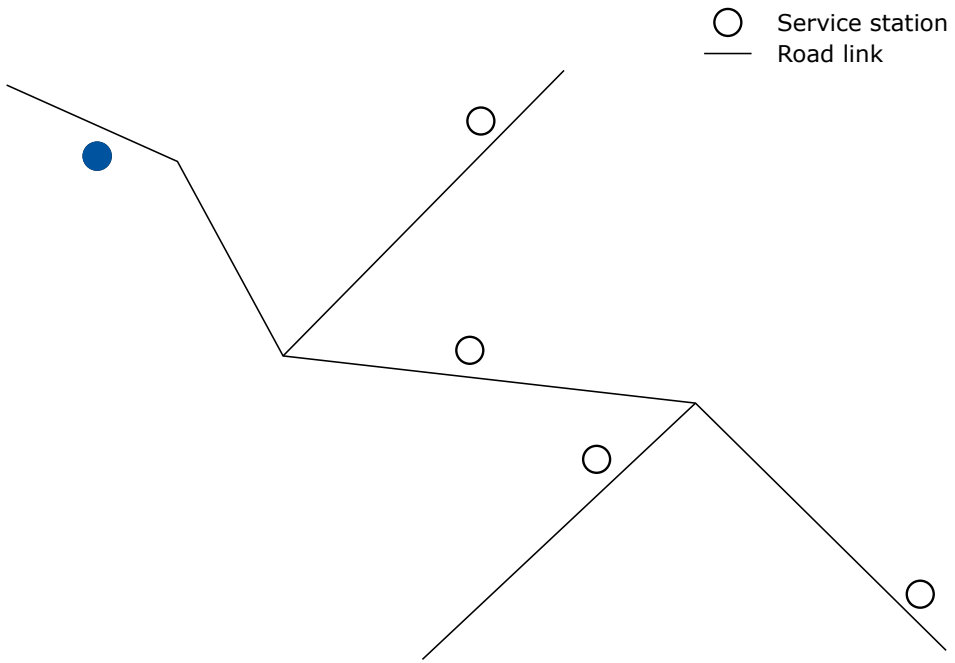

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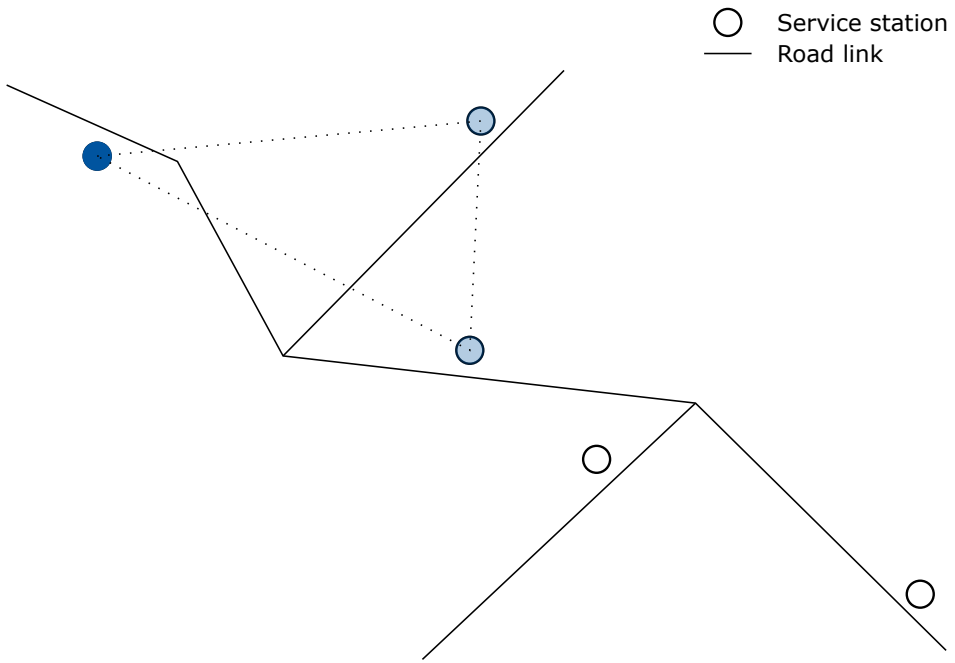

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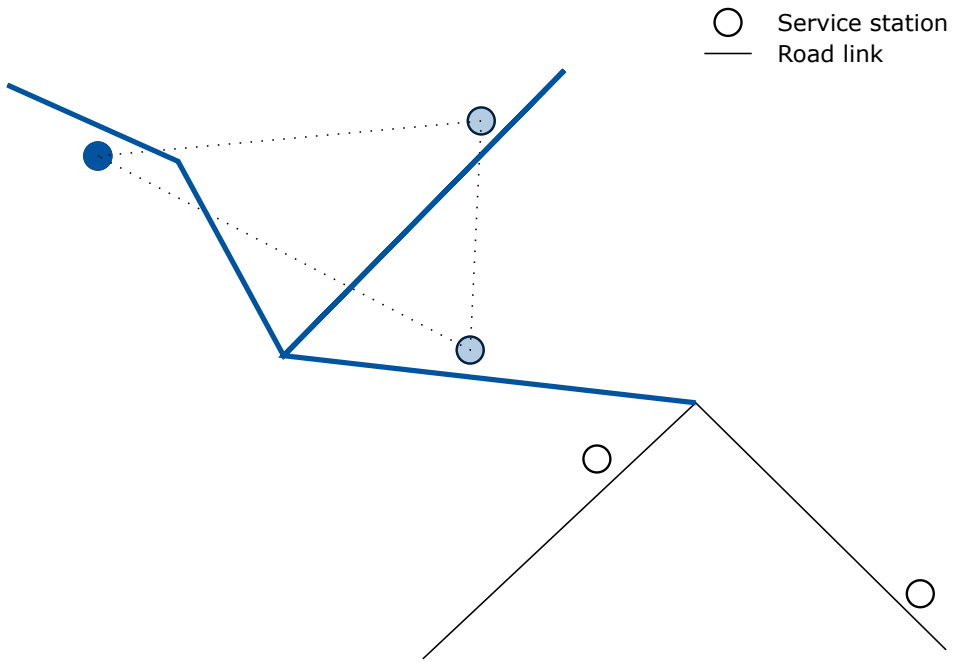

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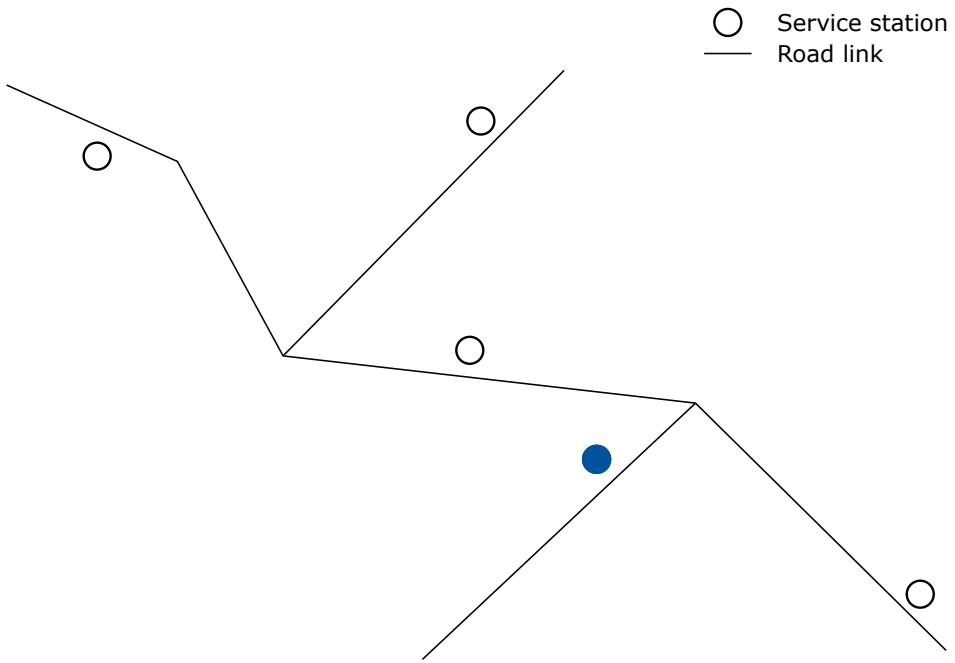

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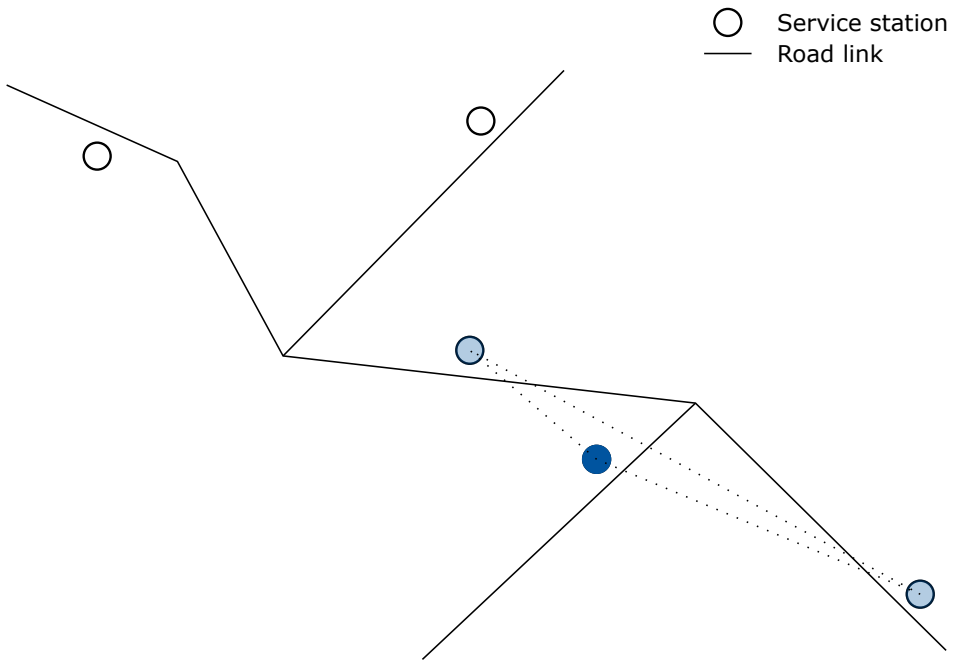

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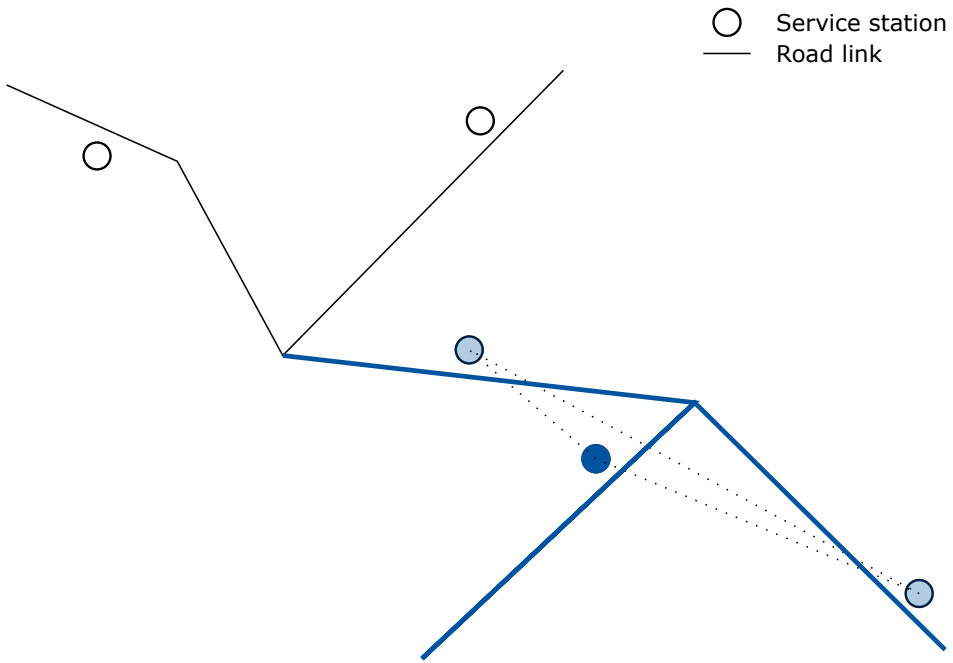

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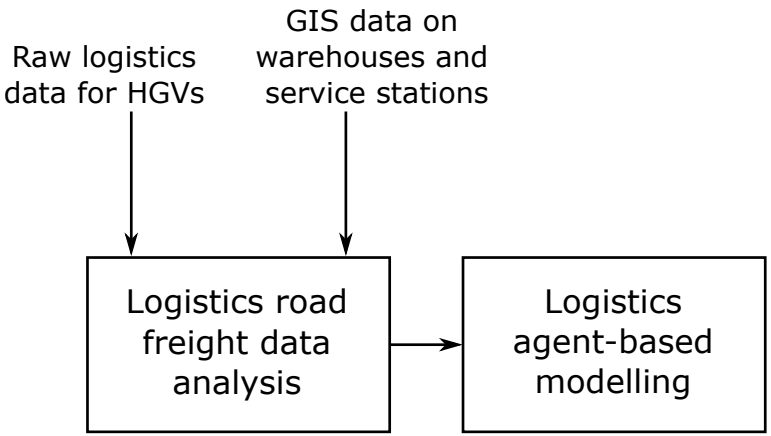

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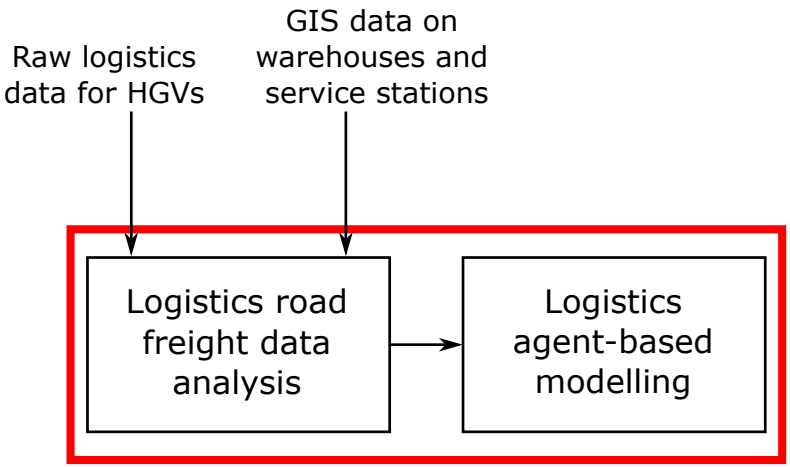
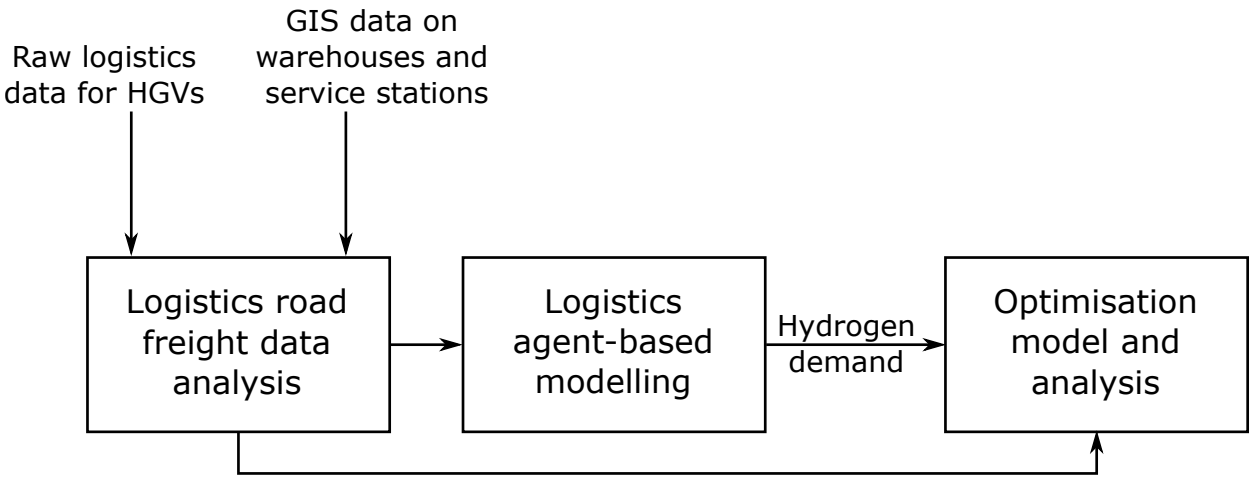
Refuelling points

- Type of refuelling point
- Fuel fulfilment capacity
- Service speed
- Number of HGVs served
- Fuel level
- Effectiveness

Mapping current HGVs refuelling demand



Research Methodology



Research Methodology

Optimise refuelling points

Research Methodology

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- Minimise number of refuelling points

Research Methodology

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- Compare emergence with optimisation algorithm outputs

Research Methodology

Resilience and robustness

Research Methodology

Resilience and robustness

- System must adapt to changes in demand profile

Research Methodology

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- Understand failure modes

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Research Methodology

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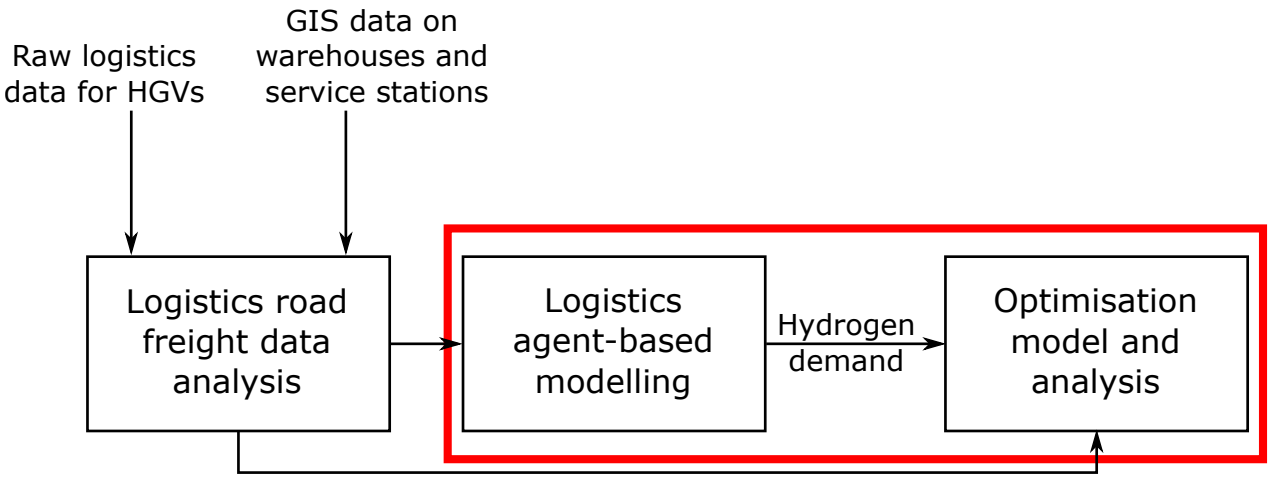
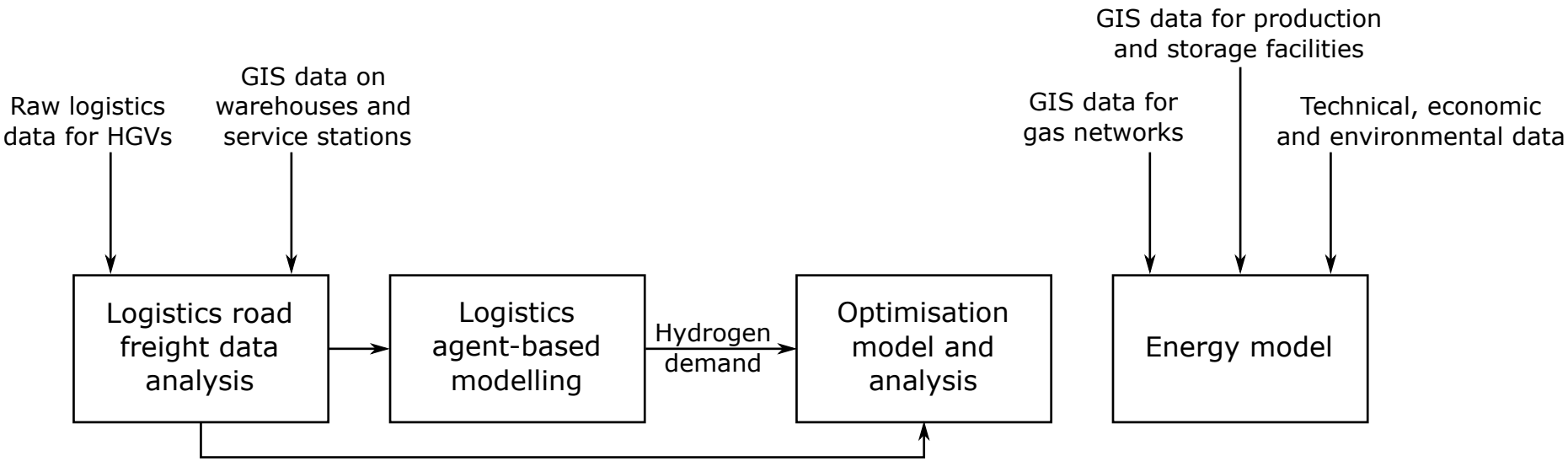
- System must adapt to changes in demand profile
- Understand failure modes
- Real-world implications (main road preference, direction of travel)
- At least one refuelling point in x distance range with a second (back-up) refuelling point within βx distance range

Research Methodology

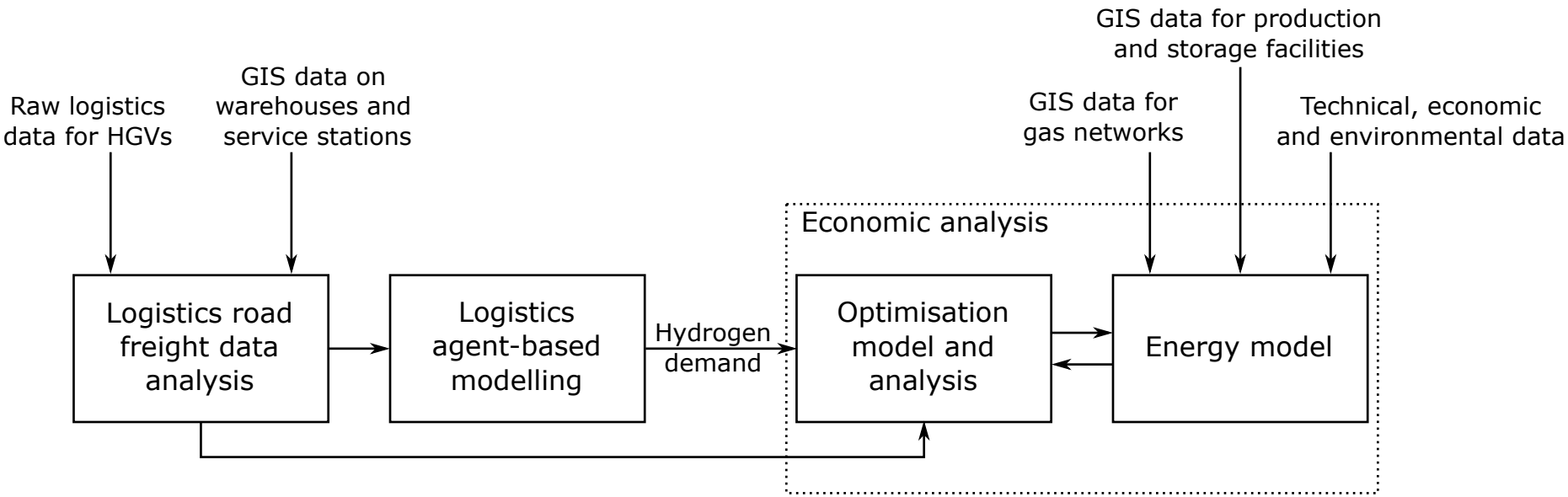
Agent-based simulation model with optimisation capabilities



Research Methodology

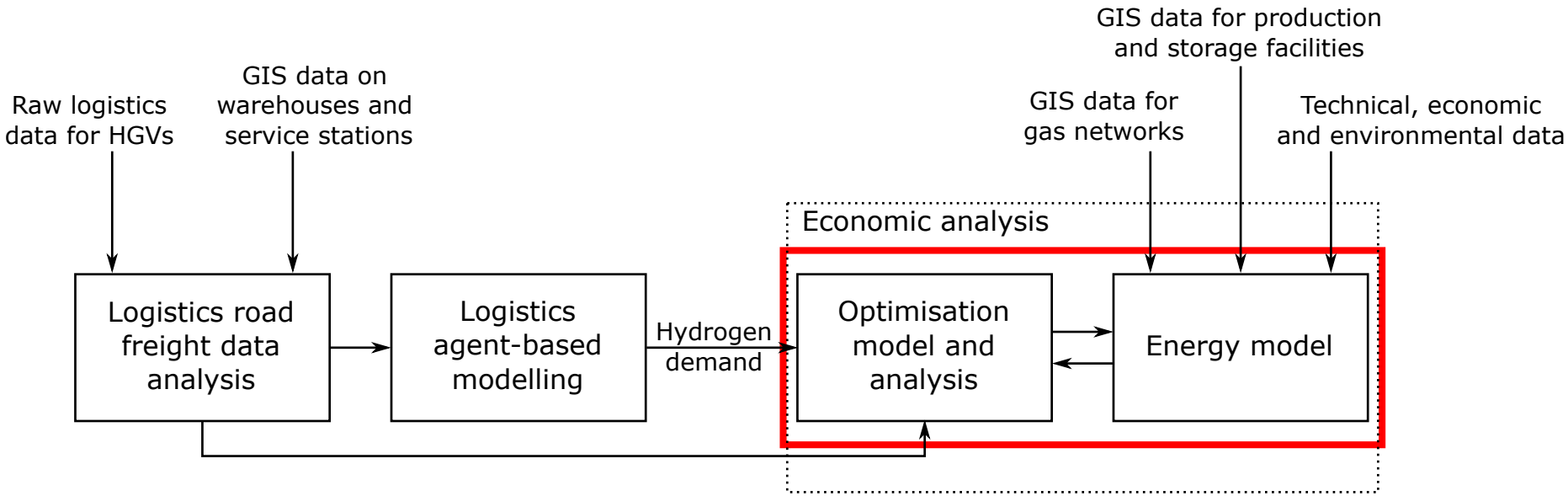


Research Methodology



Research Methodology

Scenario and economic analysis



Research Methodology