Worms 2024

SGR-Chain: Network Design

Prof. Dr. David Francas

Objectives

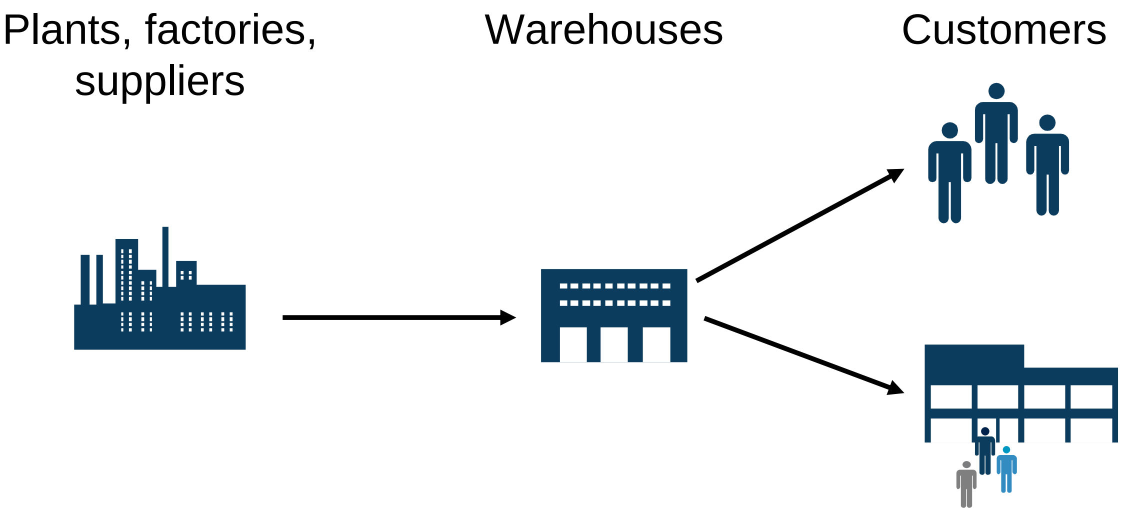
- **What are the key objectives of this module?**

- After this module, you will be able to:
  - Understand the **drivers of network design** and the **key elements of network modelling**
  - Understand how **service**, **sustainability** and **cost tradeoffs** influence network design decisions
  - Develop **network design strategies** for a distribution network

Agenda

1	Supply chain network design
2	Case study: Network design

The supply chain



- The physical **supply chain** is the collection of facilities such as plants, factories, suppliers, warehouses, needed to get a product from the source to the customer

Source: Watson et al. (2013)

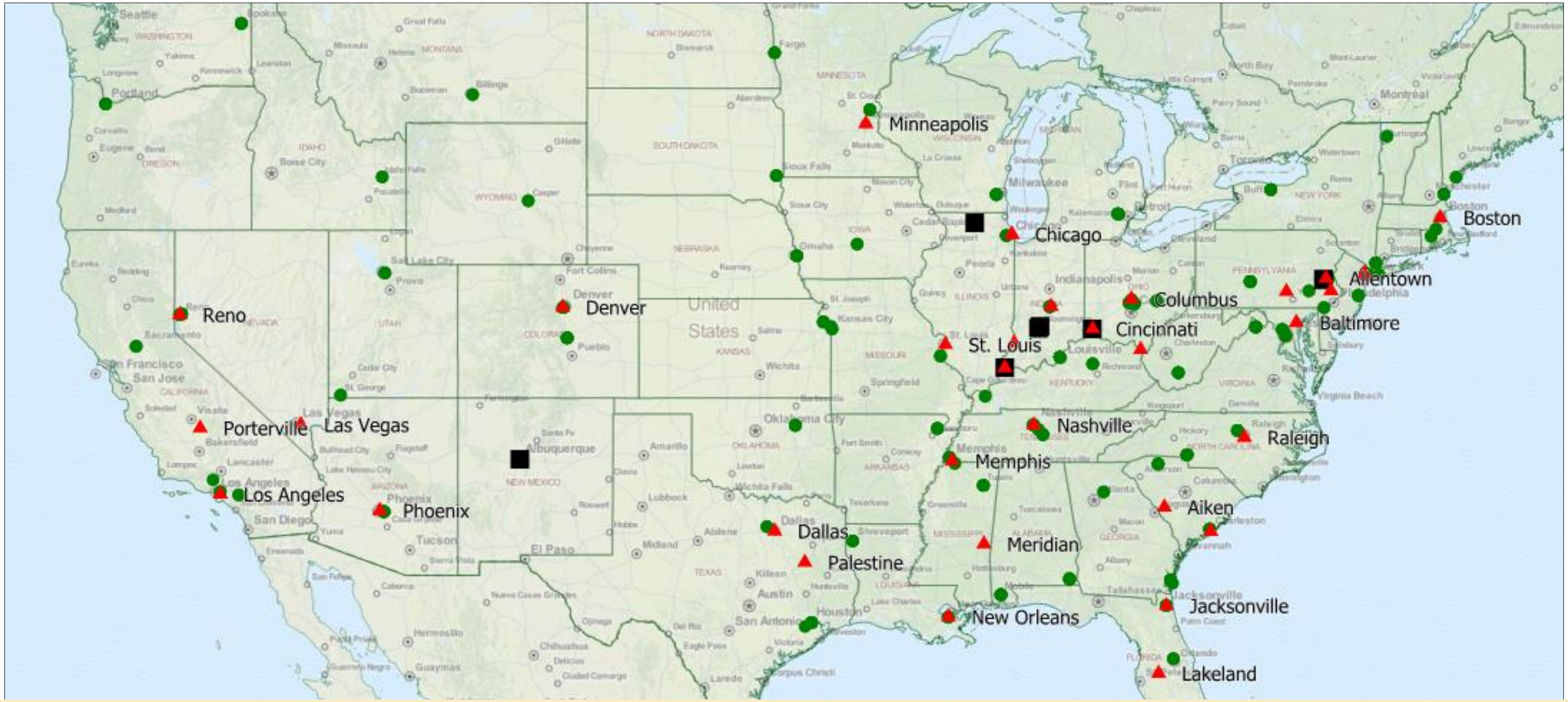
What is supply chain network design?

- The discipline used to determine the **optimal location** and **size of facilities** and the **flow through the facilities** is called **network design**
  - How many plants should we have?
  - How many warehouses should we have?
  - How should product flow?

- Network design is sometimes called **network modeling**
  - You build a mathematical model of your supply chain
  - You solve the model using optimization techniques
  - You then pick the best answer

Source: Watson et al. (2013)

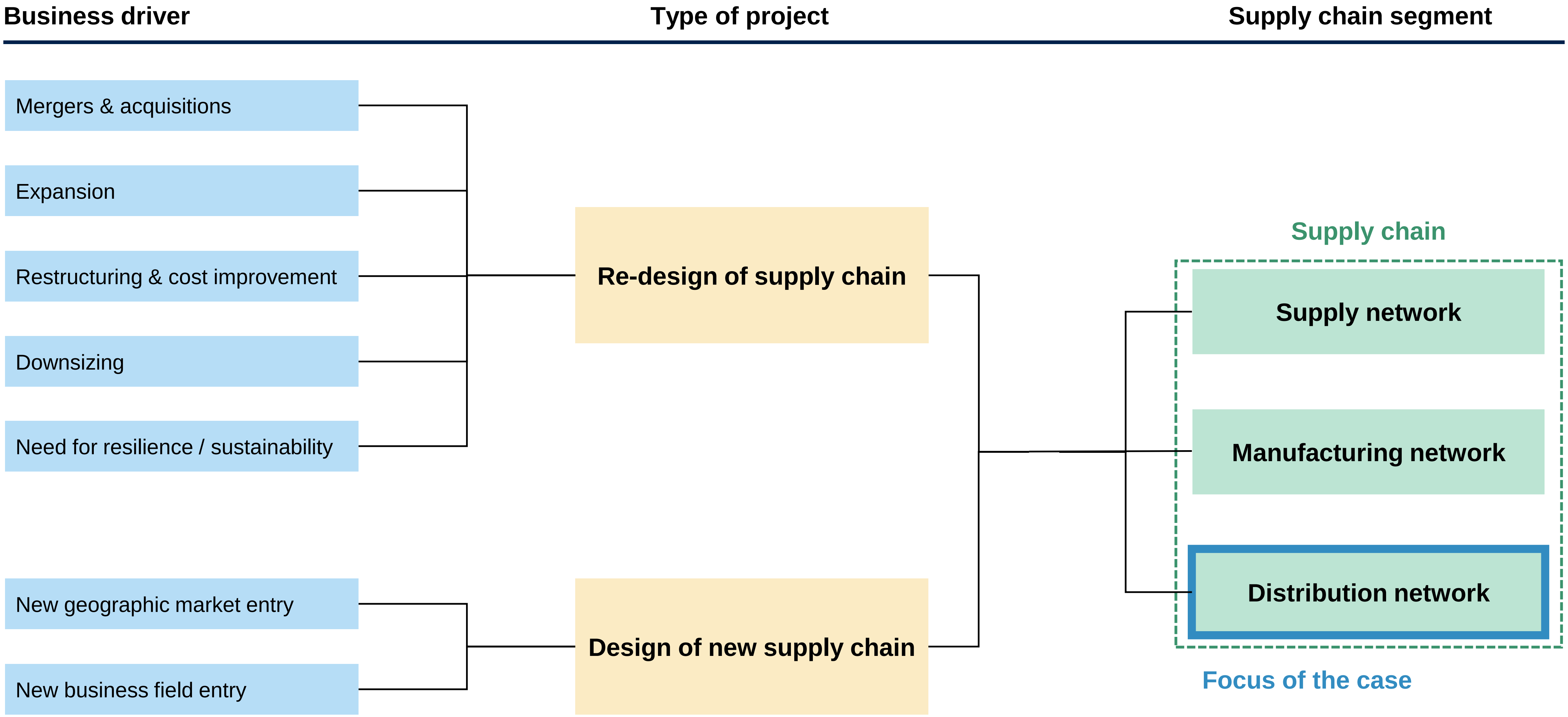
A visual look at network design



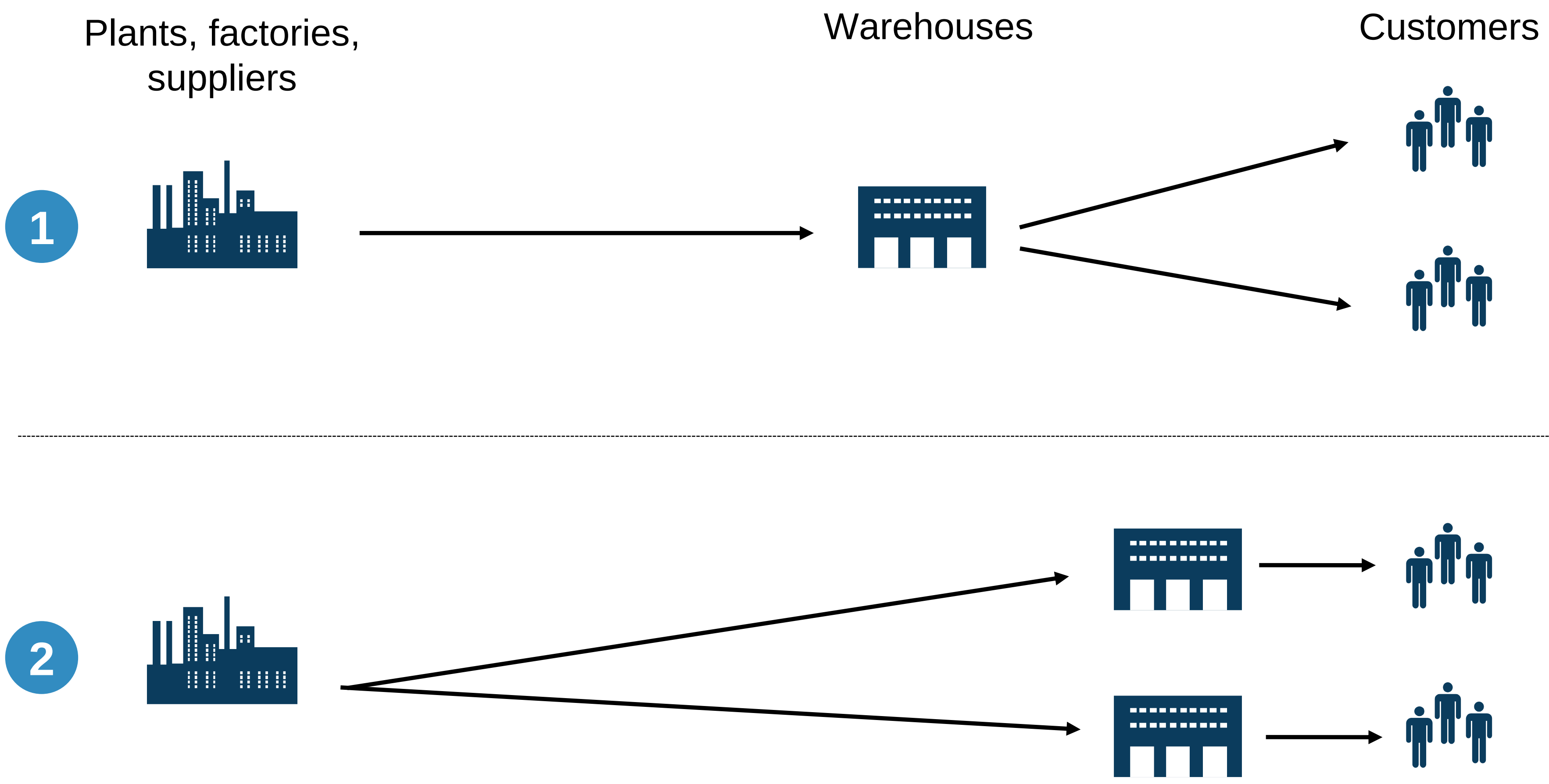
In this case, the **green dots** are our **customers**. The **black rectangles** are the **plants**. The **red triangles** across the US represent **potential warehouses**. This network design problem is about **picking the right number and locations of warehouses** to best serve the customers

Source: Watson et al. (2013)

Key business drivers and classification of strategic network design projects



Supply chain network design: Warehouse versus transportation cost

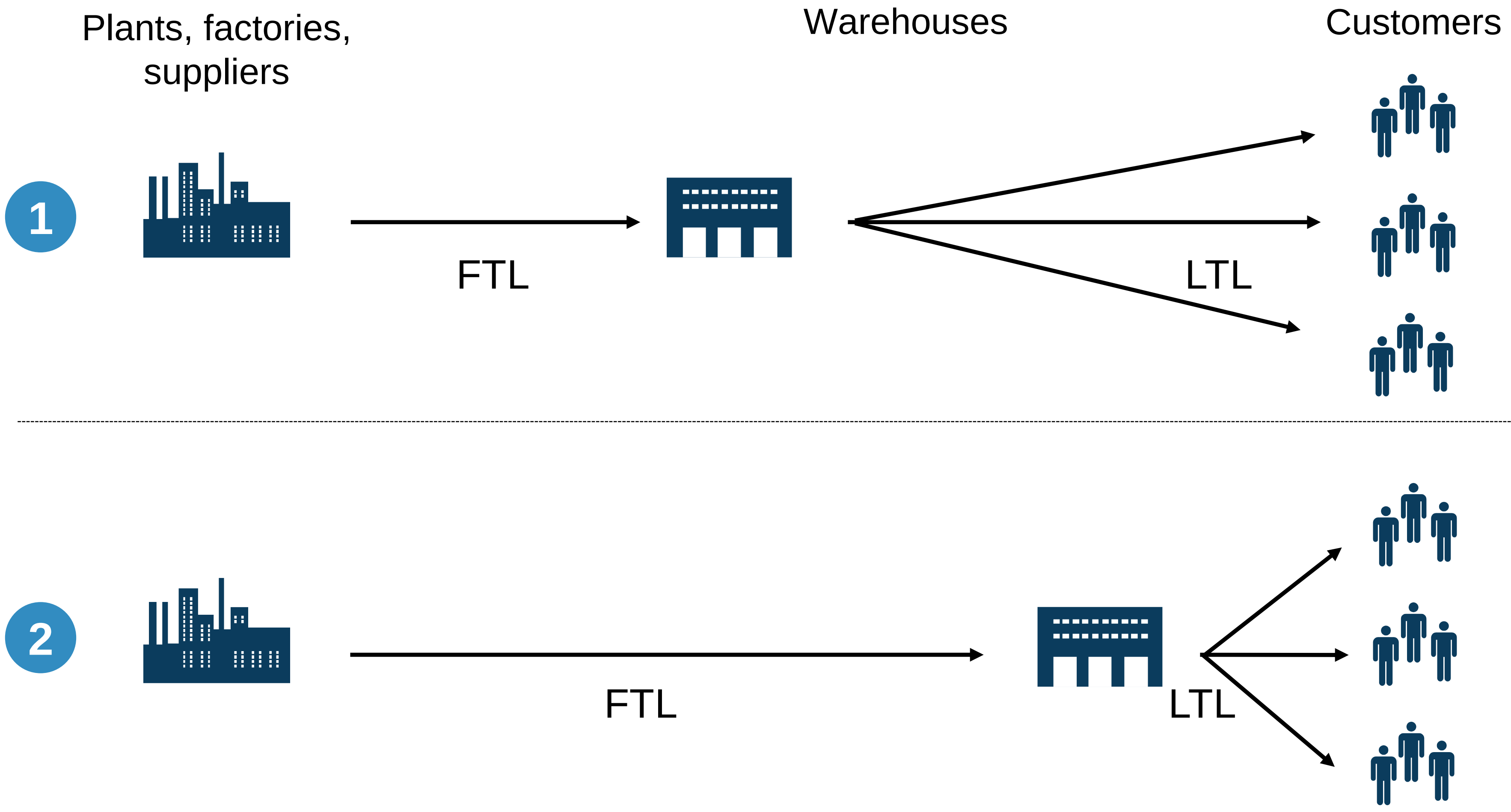


- Less warehouses but longer distances to customers
- Lower warehousing but higher transportation cost

- Higher warehousing but lower transportation cost

Source: Adapted from Watson et al. (2013)

Supply chain network design: Inbound versus outbound transportation cost

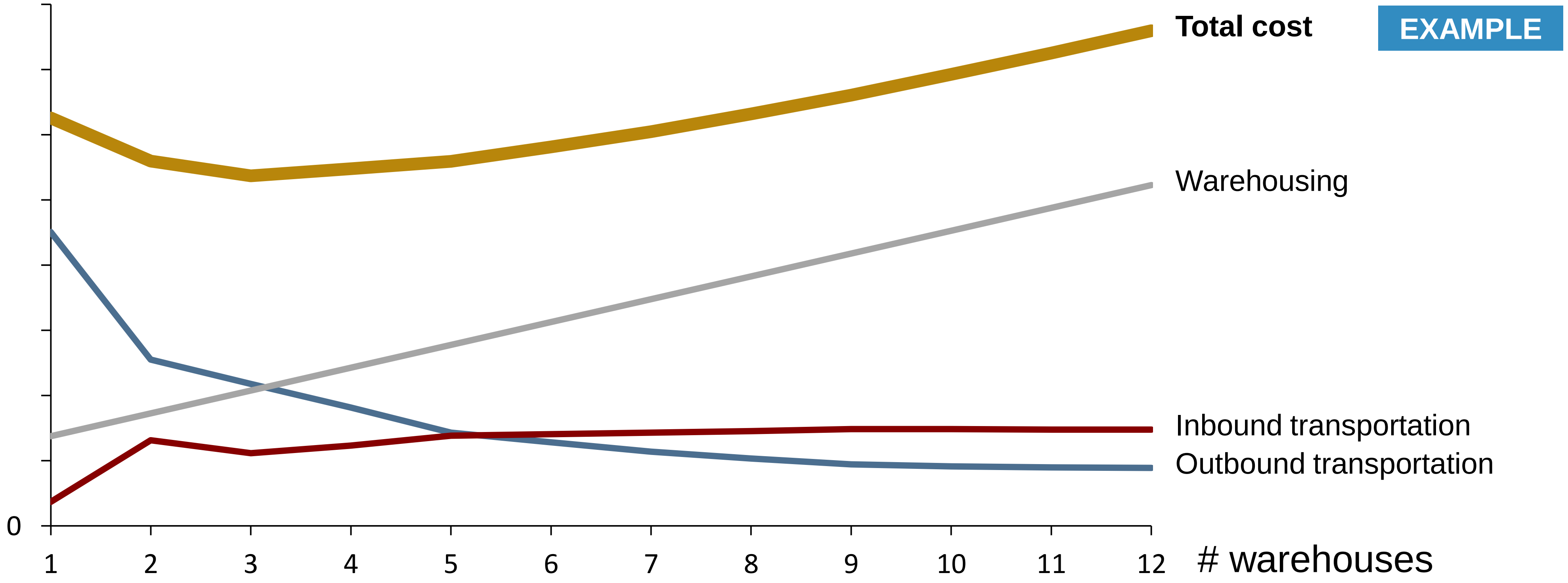


- Full truckload (FTL) cheaper per unit than less than truckload (LTL)
- Lower inbound transportation but higher outbound transportation cost

- Higher inbound transportation but lower outbound transportation cost

Source: Adapted from Watson et al. (2013)

There are many tradeoffs in network design: Centralization versus decentralization



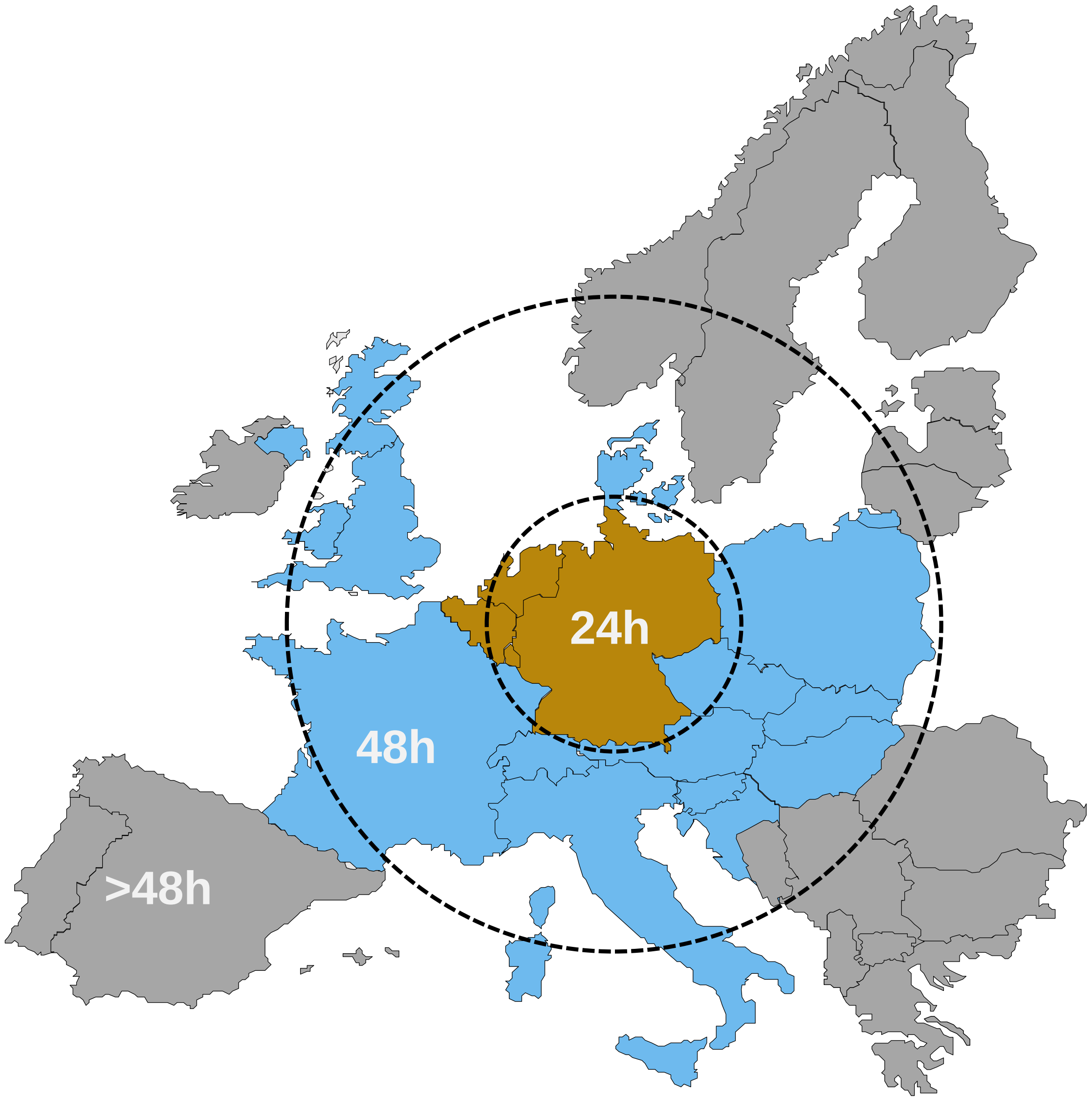
- Warehouse cost vs. transportation is one tradeoff
- There is a trade-off between inbound and outbound transportation, too
- Furthermore, there is the consideration of different costs and capacity at different locations (for example, location A is less expensive than location B)
- Lastly, the avoidance of CO_2 emissions and risk and service considerations can influence network design

Service level in network design

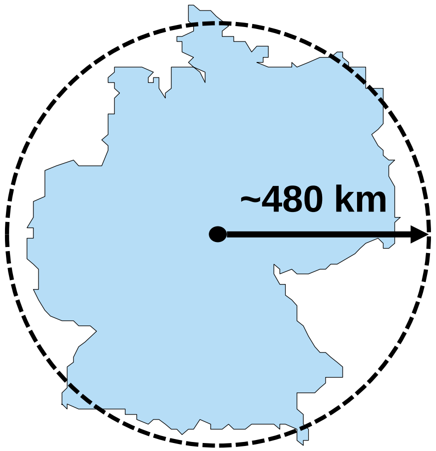
- The term “service level” is used too much without definition:
    - It has many different meanings
    - Unclear definitions do not lead to clear solutions
- Valid definitions for network design:
    - Average distance to customers
    - Percent of customers within a certain distance
- Definitions not applicable to network design:
    - Fill rate
    - Late orders
- Valid service-level constraints:
    - Maximum distance to a customer: we will express service as maximum distance to customers in the following case

Source: Adapted from Watson et al. (2013)

Service is a key constraint for a distribution network

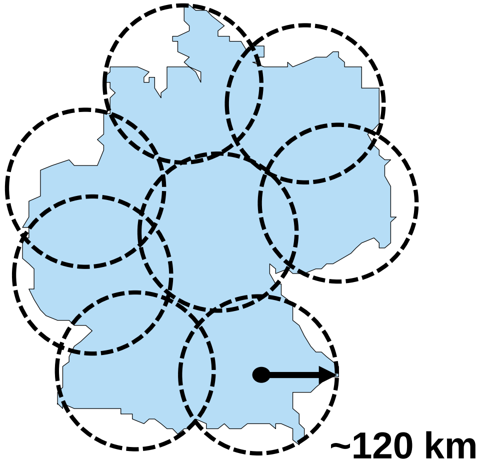


B2C-Business: Next day service



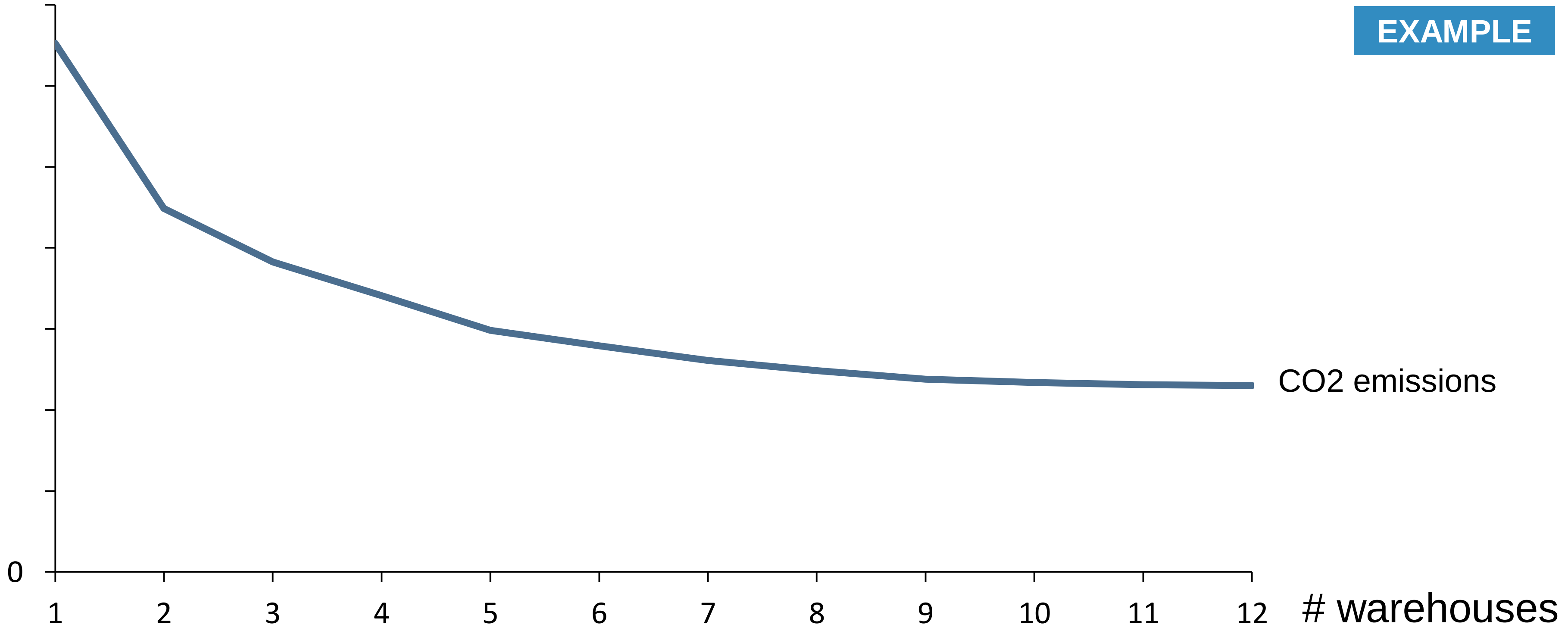
- „Next day service" can be ensured with one location in Germany
- Incoming orders: till 16:00
- Delivery: the next day

B2C-Business: Same day service



- "Same day service" can be ensured with 8 locations in Germany
- Incoming orders: till 12:00
- Delivery: from 16:00

CO2 emissions in transportation depend on network design



- The **degree of network centralization** influences the transportation distances in a network and thus carbon dioxide (CO2) emissions.
- **Carbon pricing** assigns a cost to the emission of CO2, typically based on CO2 ton equivalents.

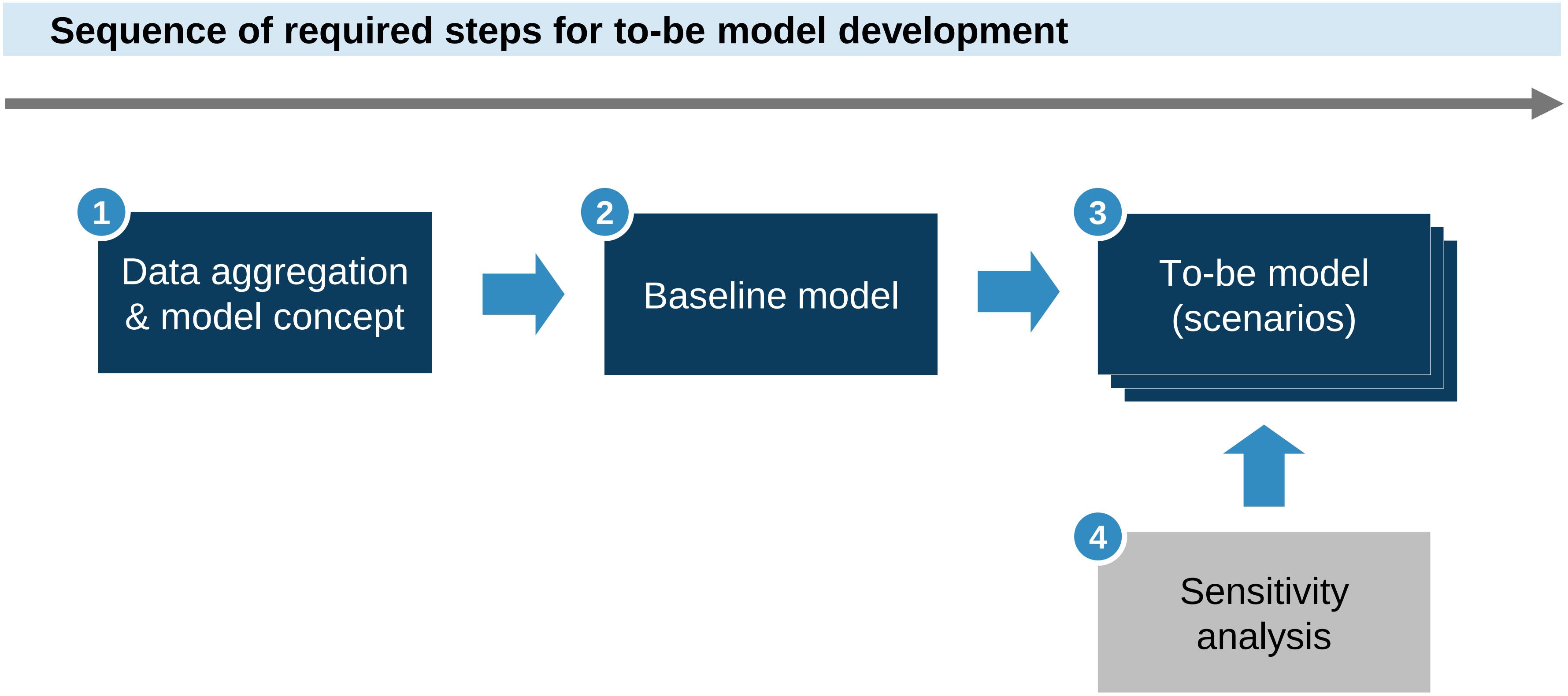
How to measure CO2 emissions in transportation?

- **Accounting for Fuel Emissions:**
  - **Well-to-Tank (WTT):** WTT emissions consist of all processes between the source of the energy (the well) until the point of use (the tank)
  - **Tank-to-Wheel (TTW):** TTW focuses solely on the energy conversion and emissions during vehicle operation
  - **Well-to-Wheel (WTW):** These are emissions from the full fuel life cycle, and should be equivalent to the sum of WTT and TTW emissions

- **Network design** can influence **TTW** on a lane by**:**
  - **Route optimization:** Minimize travel distance and avoiding empty runs
  - **Transportation mode:** TTW differs for e.g., train, LTL, FTL
  - **Load optimization:** Increase the utilization of vehicles
  - **Alternative fuels infrastructure:** Invest in electric vehicles

Note: we consider TTW emission factors from the GLEC Framework (2019) in our app

How to approach network modeling?



- The **baseline model** should reflect the as-is situation of the network, **while to-be models** consider variants and changes to the network
- **Sensitivity analysis** investigates how changes to key network parameters such as cost or demand influence the optimal configuration of a network

References

- GLEC Framework. (2019). Global Logistics Emissions Council Framework for Logistics Emissions Accounting and Reporting 2.0. Smart Freight Centre.
- Watson, M., Lewis, S., Cacioppi, P., & Jayaraman, J. (2013). Supply chain network design: Applying optimization and analytics to the global supply chain. Pearson Education.

Agenda

1	Supply chain network design
2	Case study: Network design

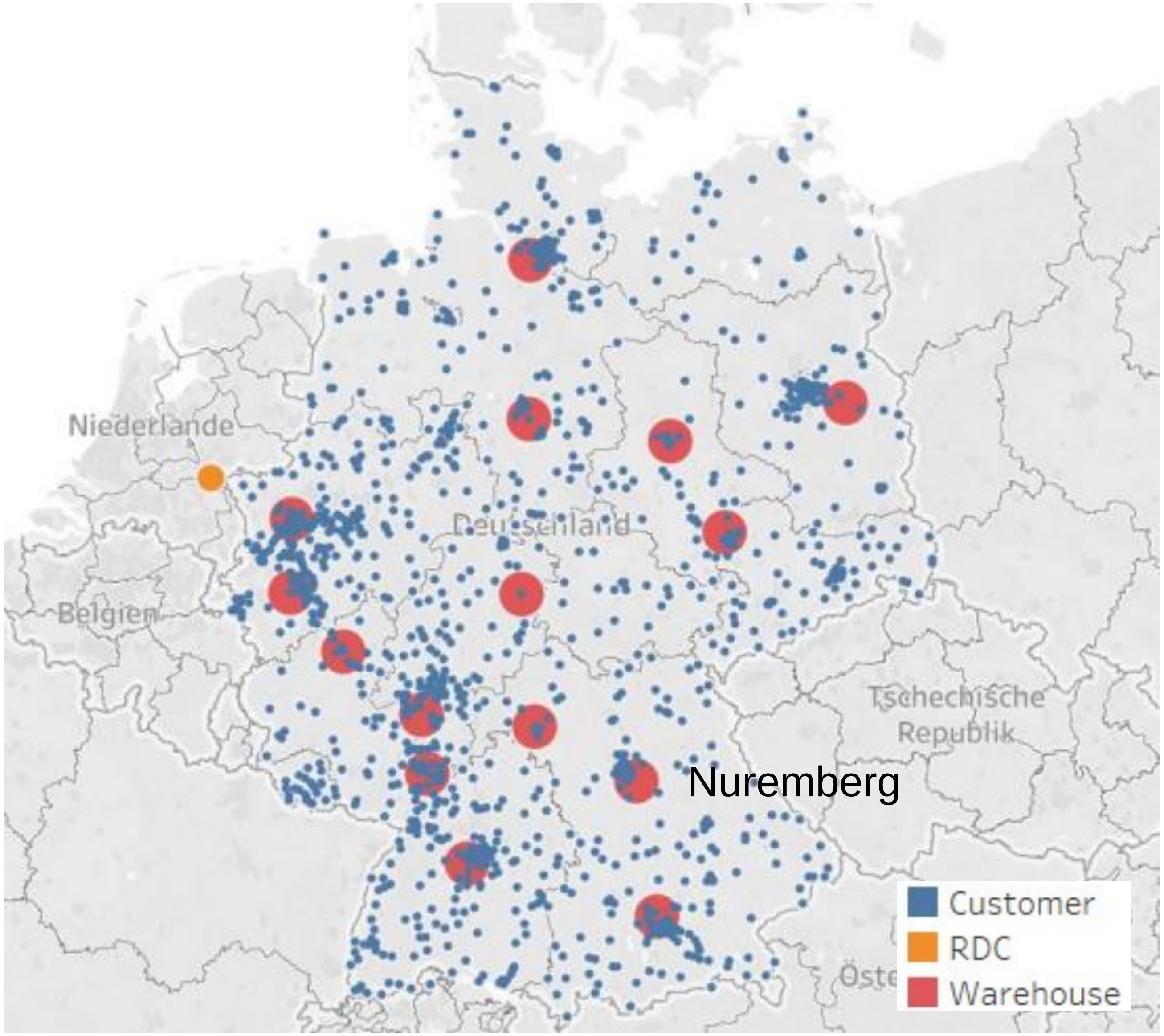
Interactive case study: Network design for Pharma Co.

Case Background

- PharmaCo is a pharmaceutical company that distributes pharmaceutical products to hospitals, pharmacies, and wholesalers in Germany. PharmaCo's products have different temperature requirements (ambient: 15-25°C, cold chain: 2-8°C) but are shipped together in a groupage network using temperature-controlled vehicles. Currently, customers are supplied from a legacy distribution center (DC) located in the Nuremberg area. The German DC is replenished from a regional distribution center (RDC) in Nijmegen, Netherlands, which consolidates inbound flows from packaging plants and contract manufacturers.

- PharmaCo is concerned about the performance of its German distribution network and has therefore initiated a network design project to review and optimize the current distribution footprint. The RDC in Nijmegen is out of scope for the network optimization project; its location is fixed and cannot be changed. PharmaCo has already identified 12 suitable locations for DCs across Germany. In addition, PharmaCo wants to assess the impact of increasing lead time requirements and environmental regulations.

Interactive case study: Current network of Pharma Co.

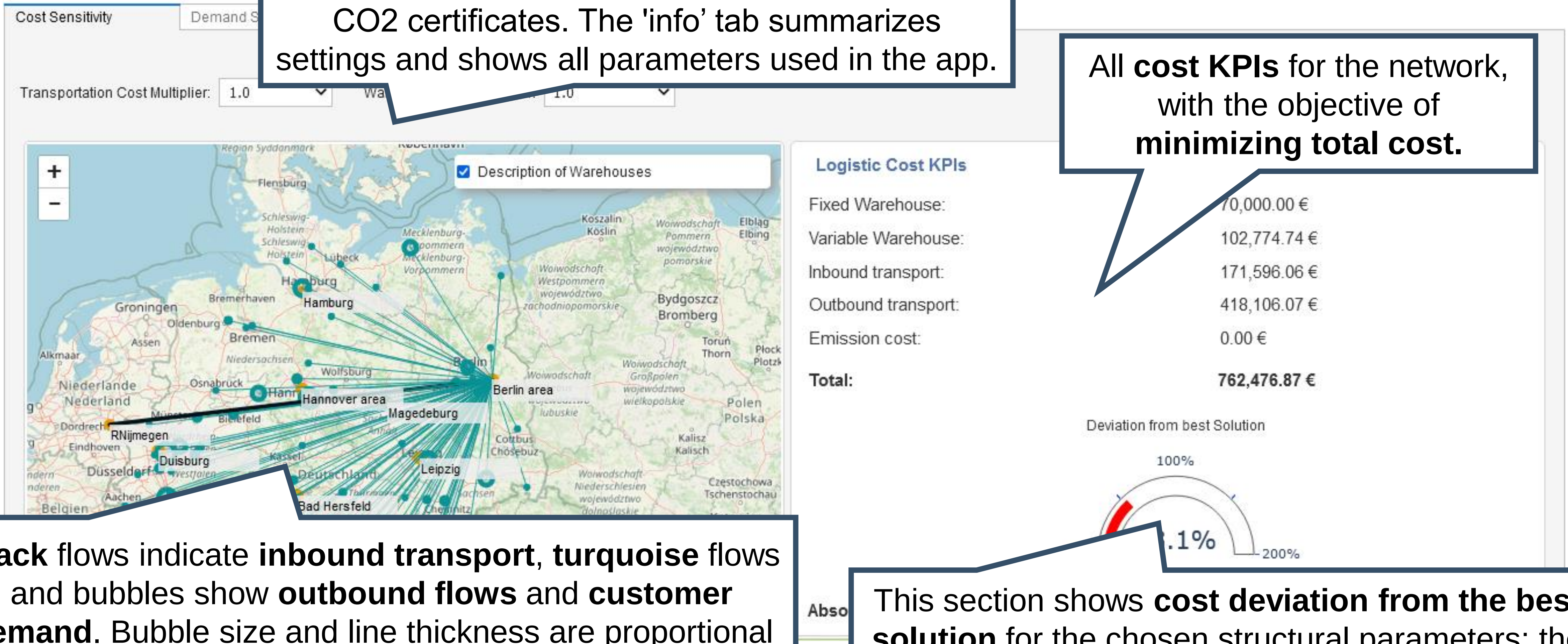


- Please note that all customers are clustered in two-digit postal code areas in the app. For example, DEU_22 represents all Germany customers with a postal code starting with 22
- All cost and demand parameters are shown in the app
- The network is modeled as uncapacitated facility location problem; all solutions in the app are optimal for chosen parameters and warehouse selection.

The network design app (1/2)

Each tab varies a structural parameter of the network: Cost, demand, lead-time, and cost of CO_2 certificates. The 'info' tab summarizes settings and shows all parameters used in the app.

All **cost KPIs** for the network, with the objective of **minimizing total cost.**



Black flows indicate **inbound transport**, **turquoise** flows and bubbles show **outbound flows** and **customer demand**. Bubble size and line thickness are proportional to volume. You can move the map and zoom in and out.

This section shows **cost deviation from the best solution** for the chosen structural parameters; the bar chart shows percentage deviation.

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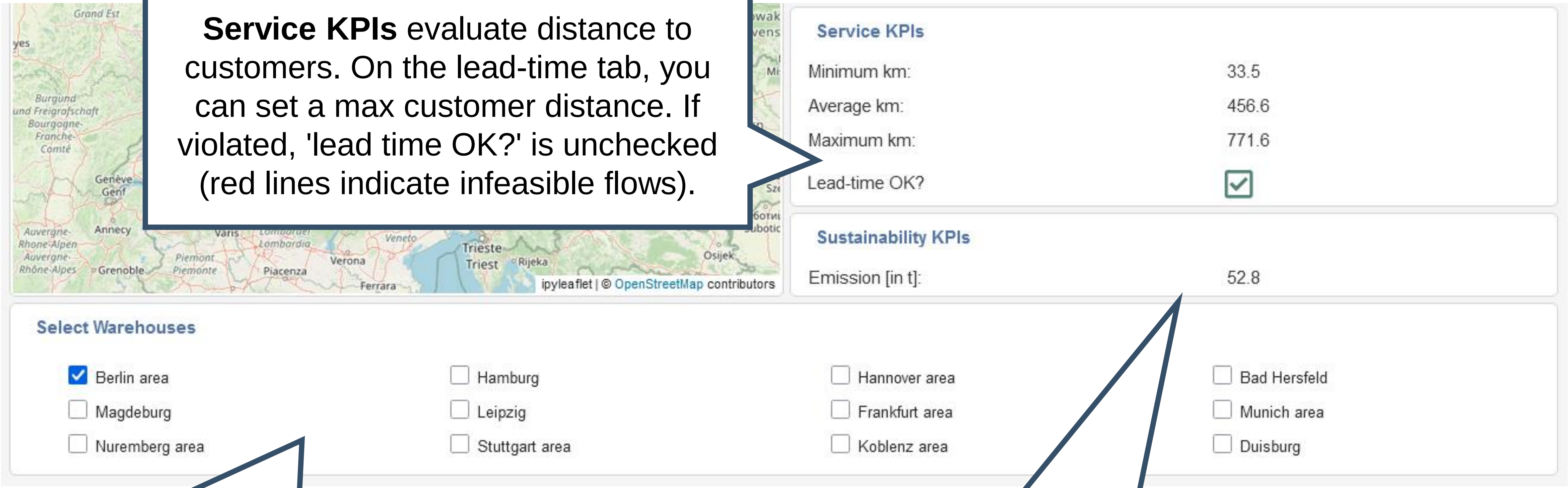
The network design app (2/2)



Service KPIs evaluate distance to customers. On the lead-time tab, you can set a max customer distance. If violated, 'lead time OK?' is unchecked (red lines indicate infeasible flows).

Select warehouses, optimal flows within the network are calculated automatically.

CO2 emissions for transportation in the network (in ton equivalents).

Network design for Pharma Co.: Tasks

Define the optimal warehouse footprint (for the chosen parameters on the current tab)

- Select the warehouse in the Nuremberg area as a baseline.
- Identify the best combination of warehouses and assess cost improvements. You can also look at the reduction CO2 emissions and service improvements (expressed as distance to customers).

Conduct a sensitivity analysis

- Each tab allows you to vary one structural parameter of the network. This includes cost changes, changes in customer demand, lead-time requirements by customers, and the impact of increasing CO2 certificate costs.
- How do optimal solutions change?