FREIGHT OVERVIEW

Outline

- Importance of freight modelling
- Introduction to the modelling approach for freight demand modelling

Significance of freight modeling

- Freight demand is a derived demand

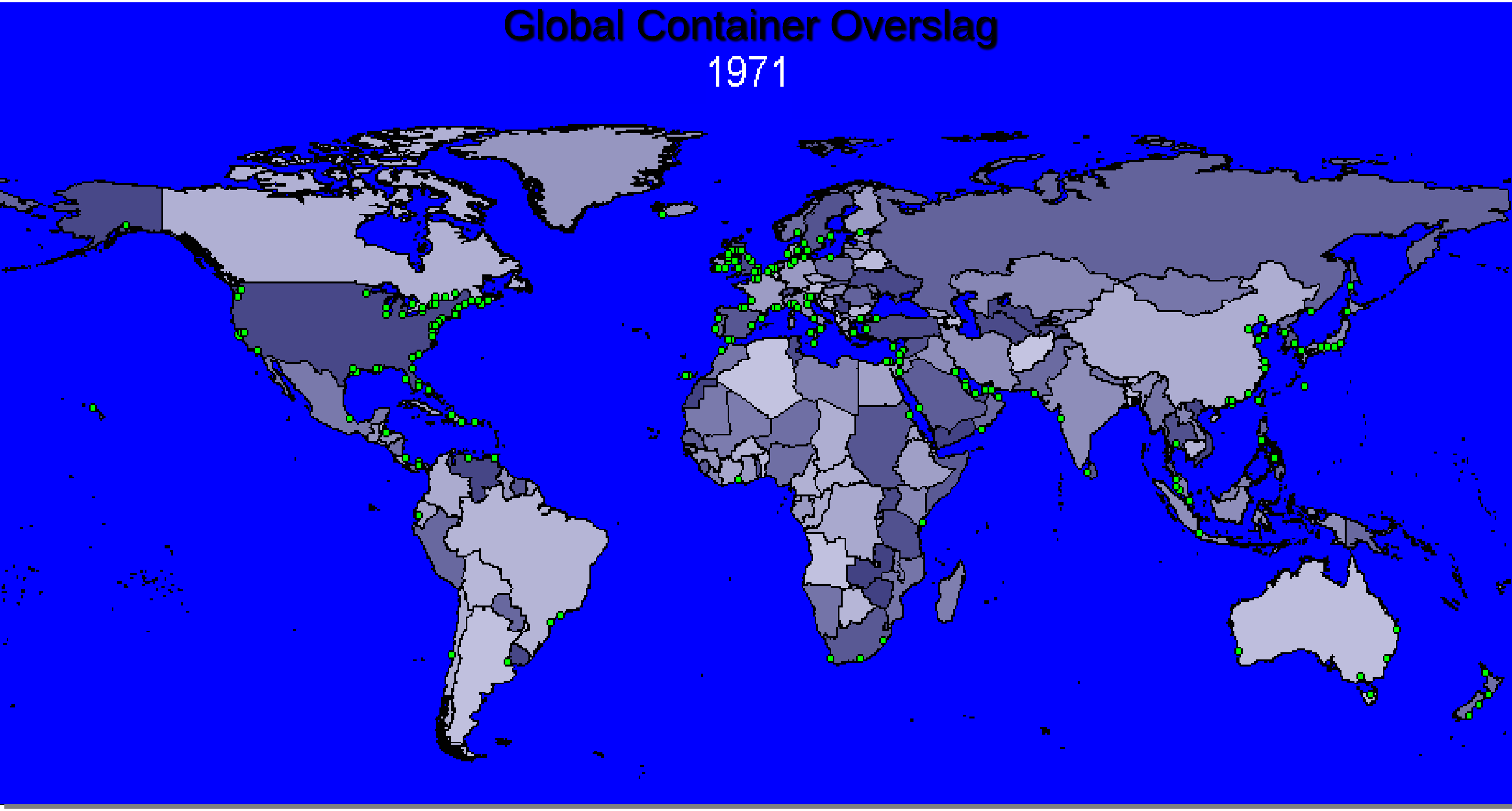
What does it take to have a cup of coffee in a café?

The combined efforts of
29 companies in 18 countries

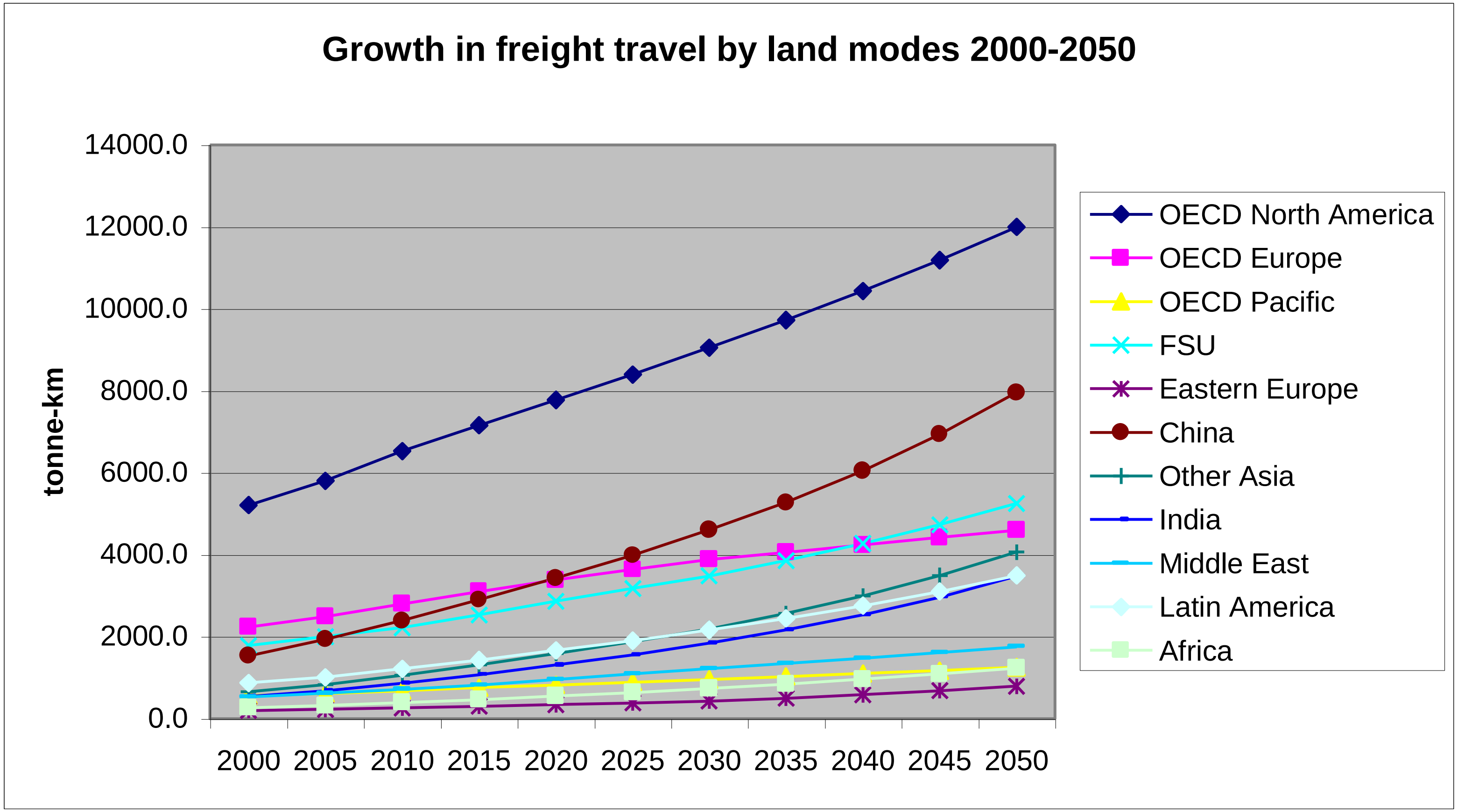
Source: IRU

- Road Transport has become a production tool!
- Globalization impacts

Globalization impacts



Freight demand forecast

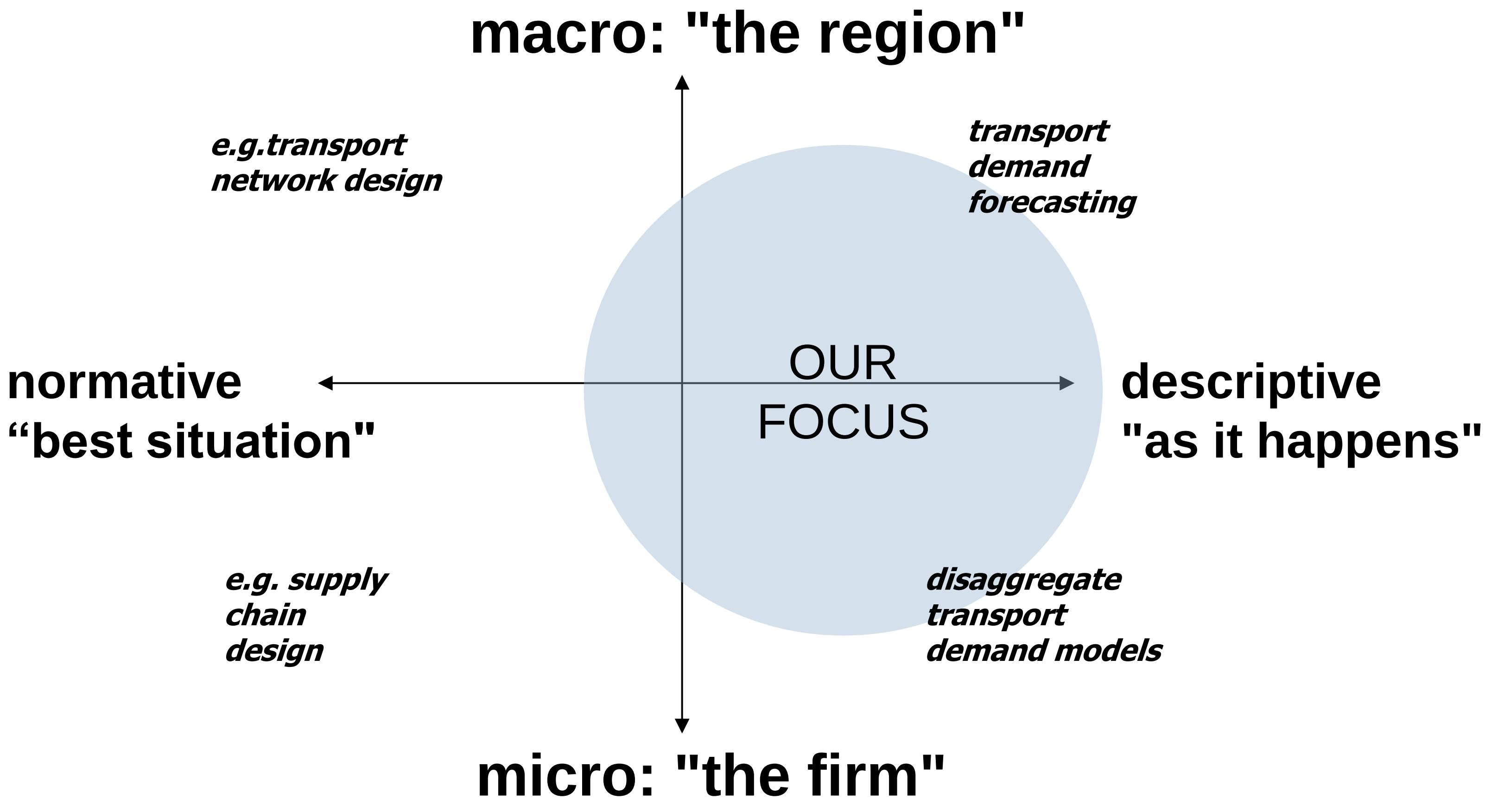


Freight demand vs auto travel demand

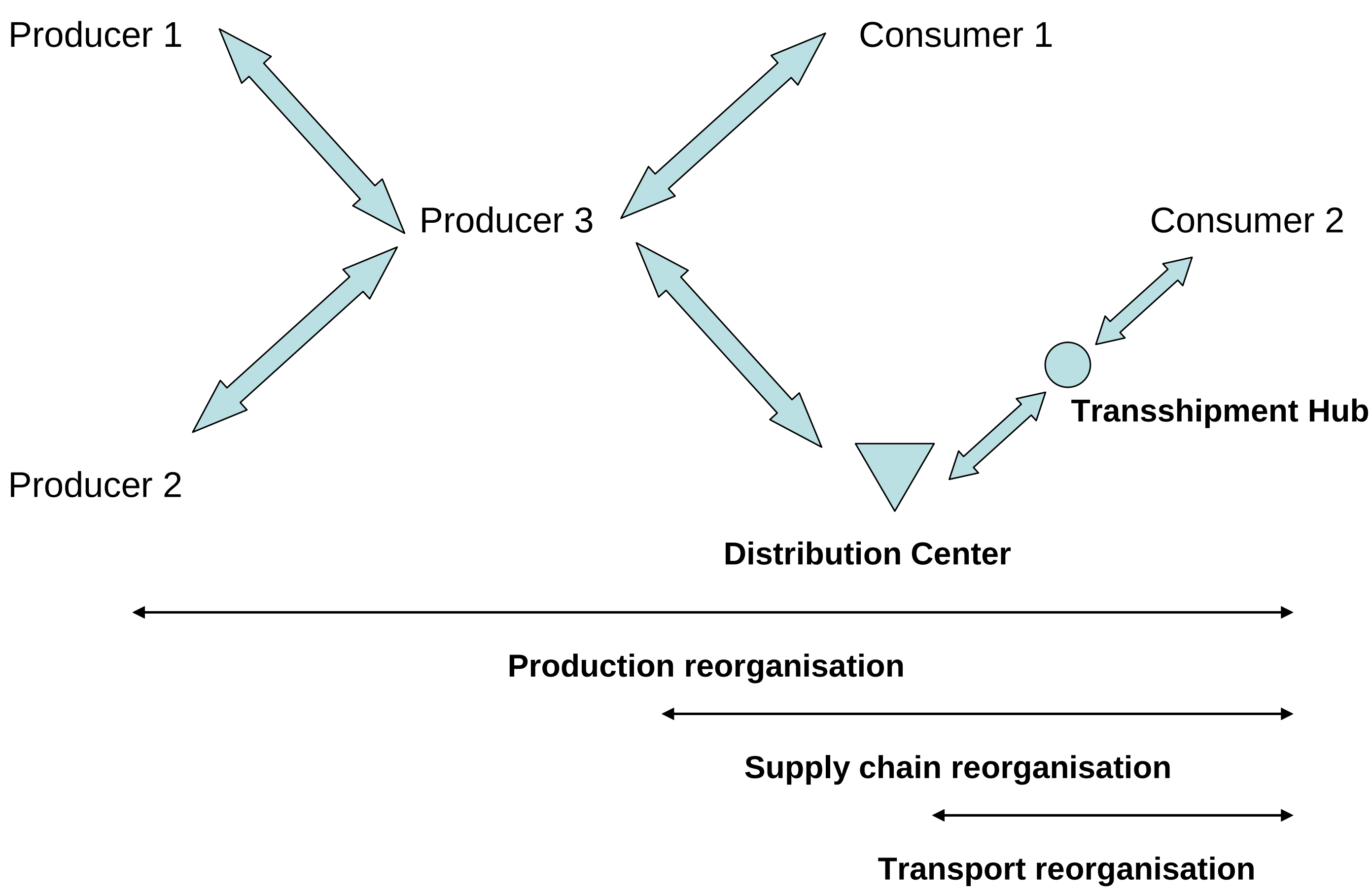
- One decision maker or many?
- Unit of transport = decision maker?
- Many interactions between decision makers, or few?
- Correspondence between demand and trips: simple or complex?
- Heterogeneity in trip purposes: low or high?

NCFRP 25. Holguin Veras et al, 2010

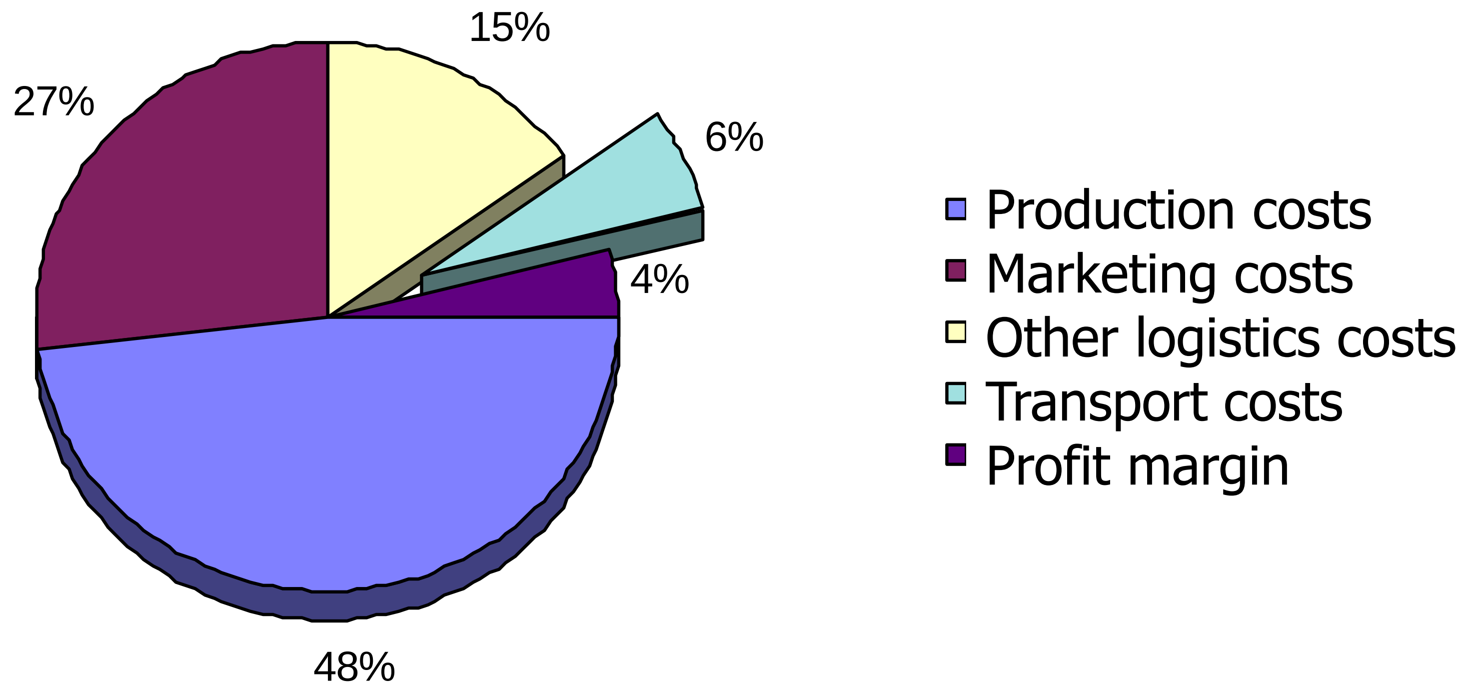
Modelling freight transport demand in the context of public policy



Bigger picture of supply demand chain

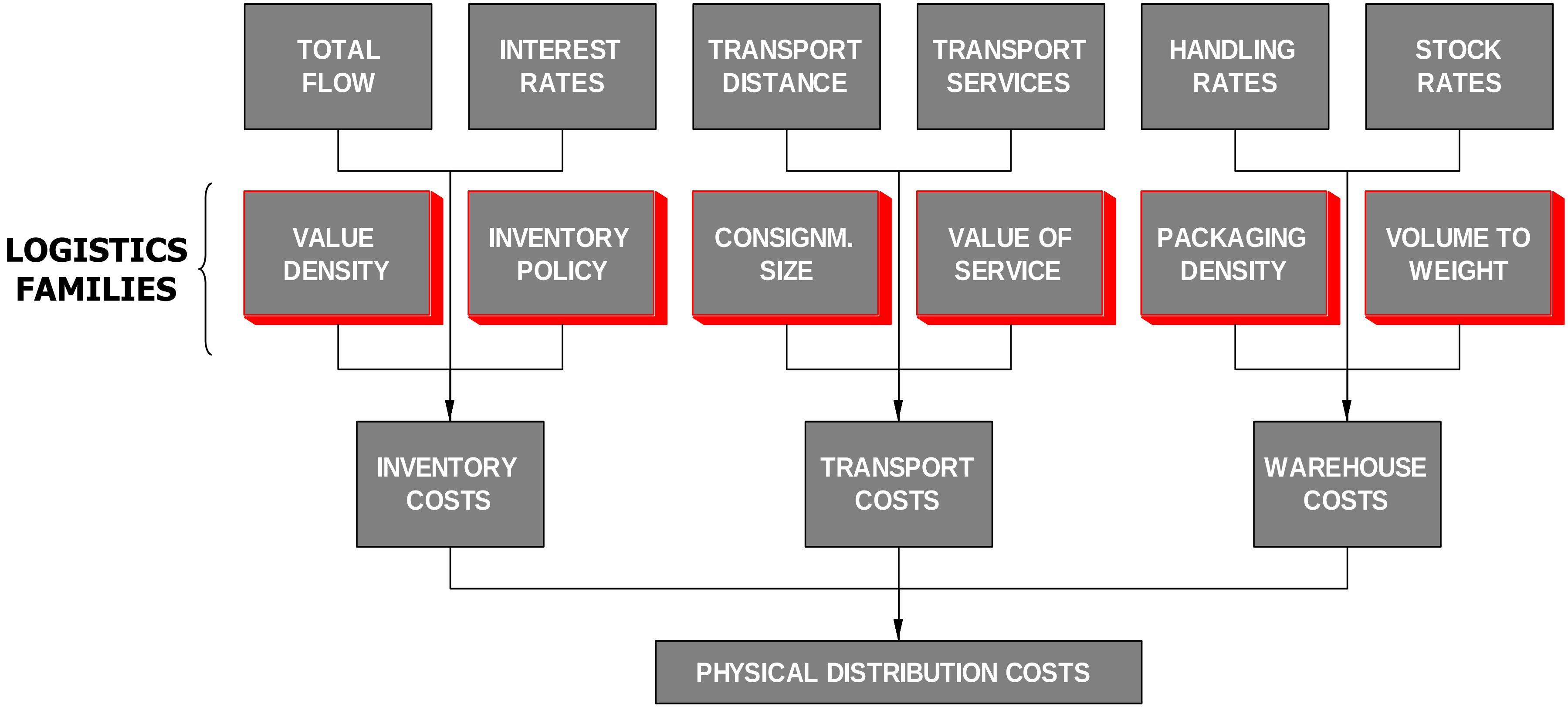


Bigger picture of supply chain



Groothedde, 2004

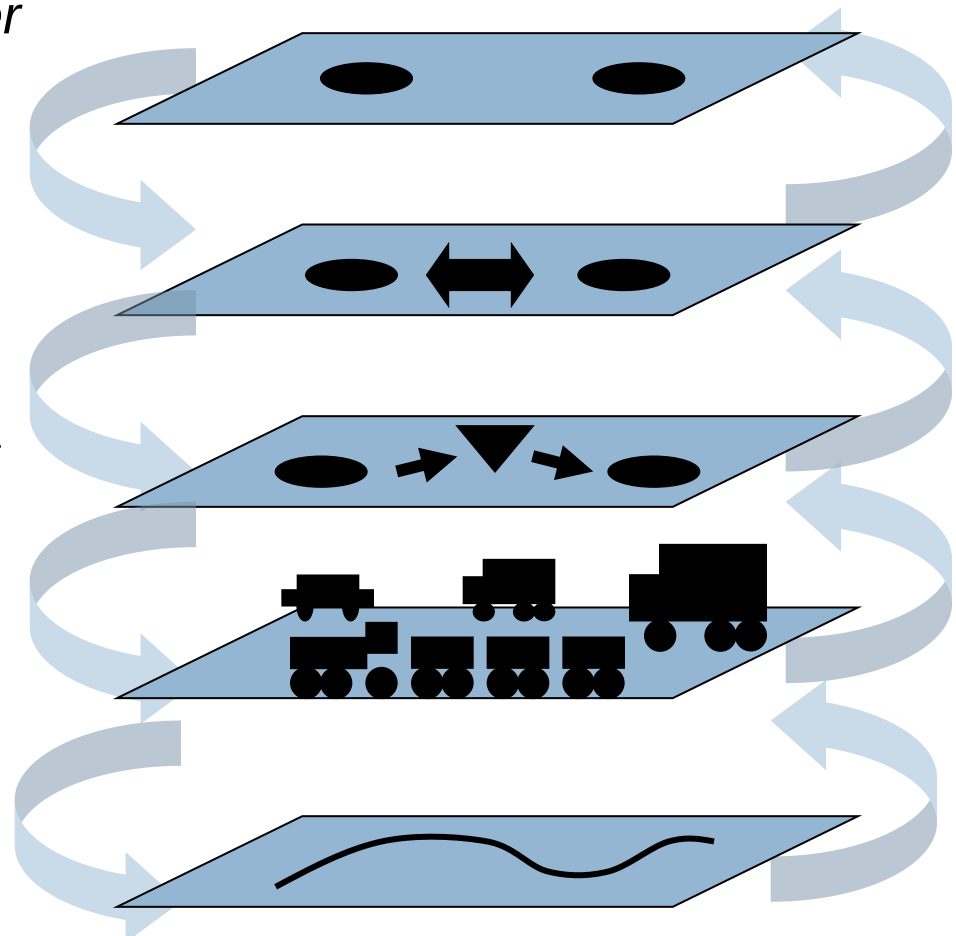
Total logistics costs: determinants



A layered model of logistics decisions

Decision maker

Decision



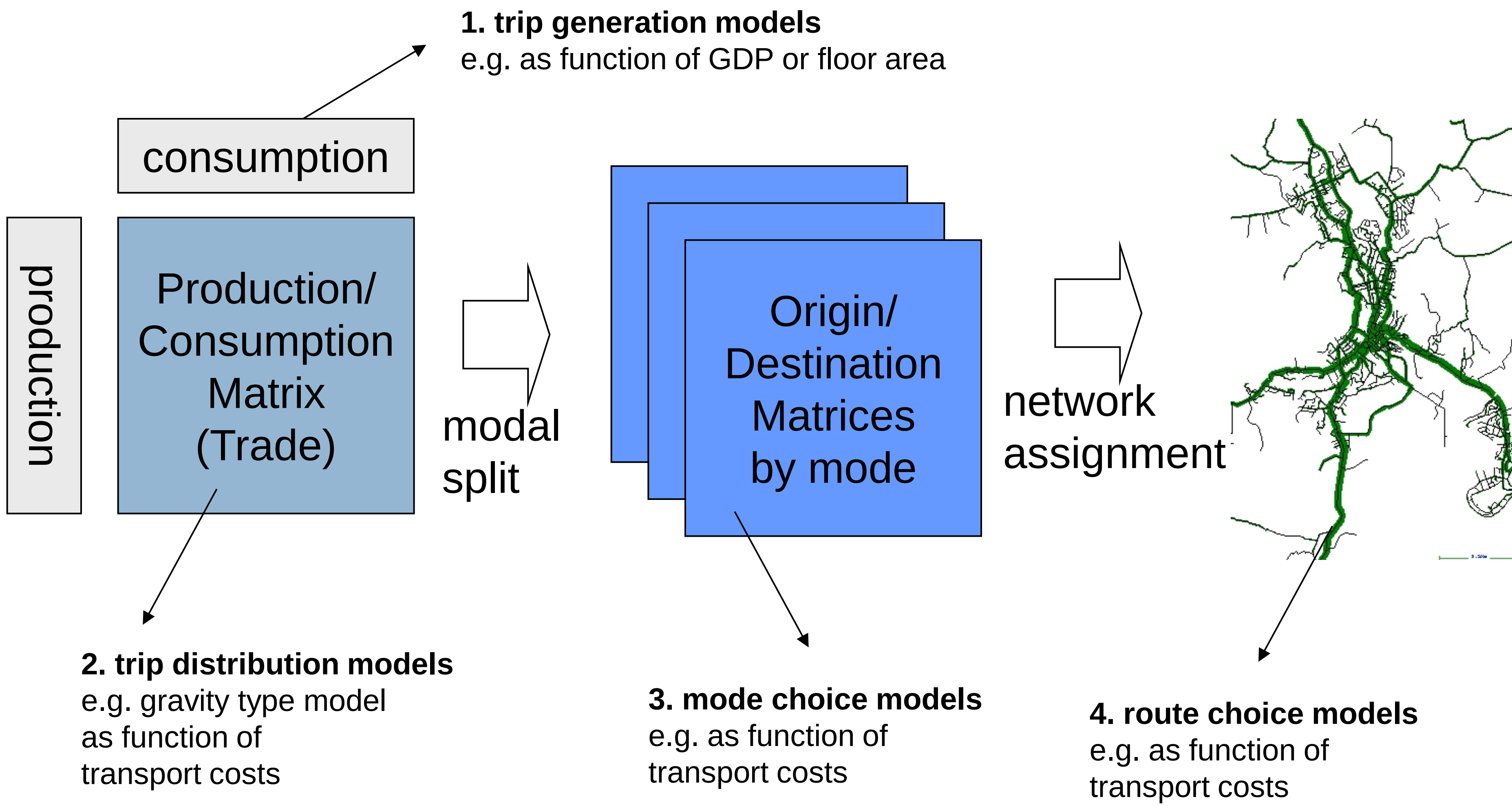
"shipper"

Decision maker	*Decision*
Producer / plant mgr. Consumers	Production Location choice Type of product Production volume Consumer choices
Sales managers Sourcing managers	Trading contracts
Logistics service provider Logistics manager	Shipment sizes, frequencies Location en volume of inventory Distribution channels

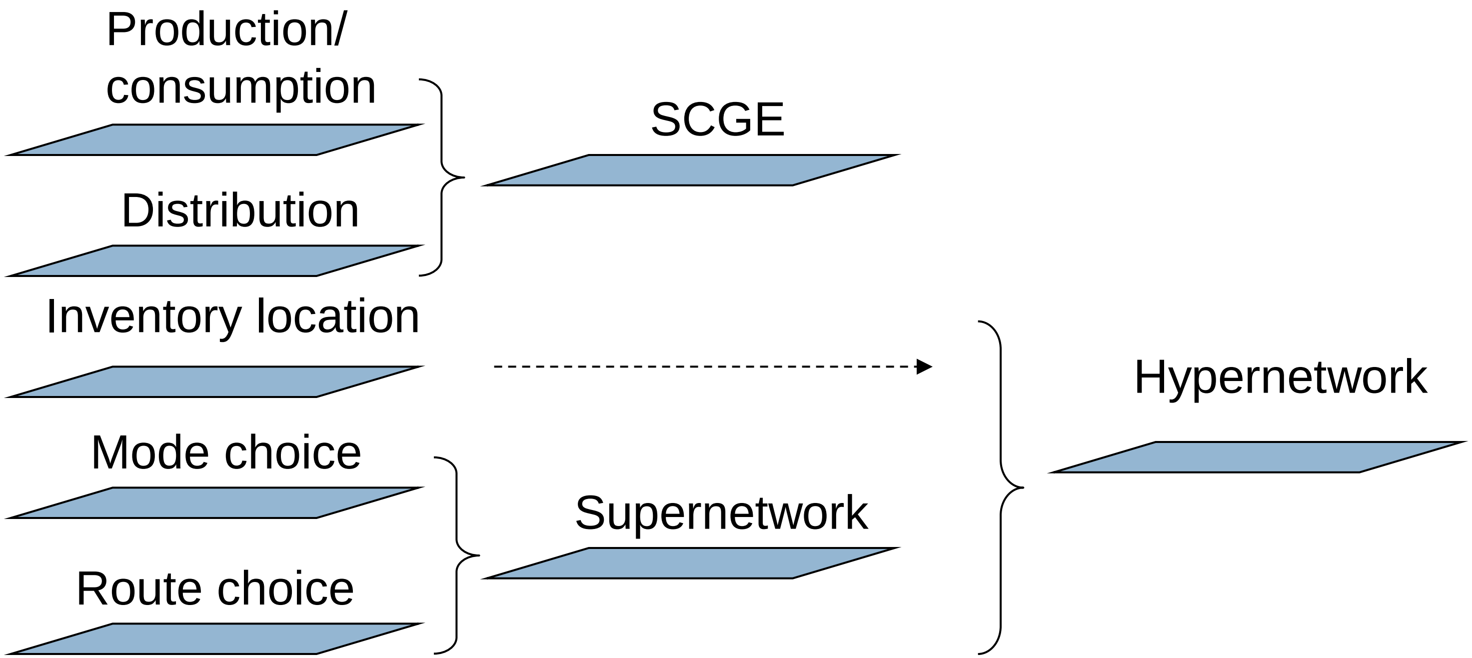
"carrier"

Decision maker	*Decision*
Logistics manager Transport manager Forwarder	Mode(s) of transport DIY or Hire & Reward? Long term or spot contract? Means of transport
Transport planner Driver	Routing and scheduling Time of departure Capacity planning

The conventional 4-stage model

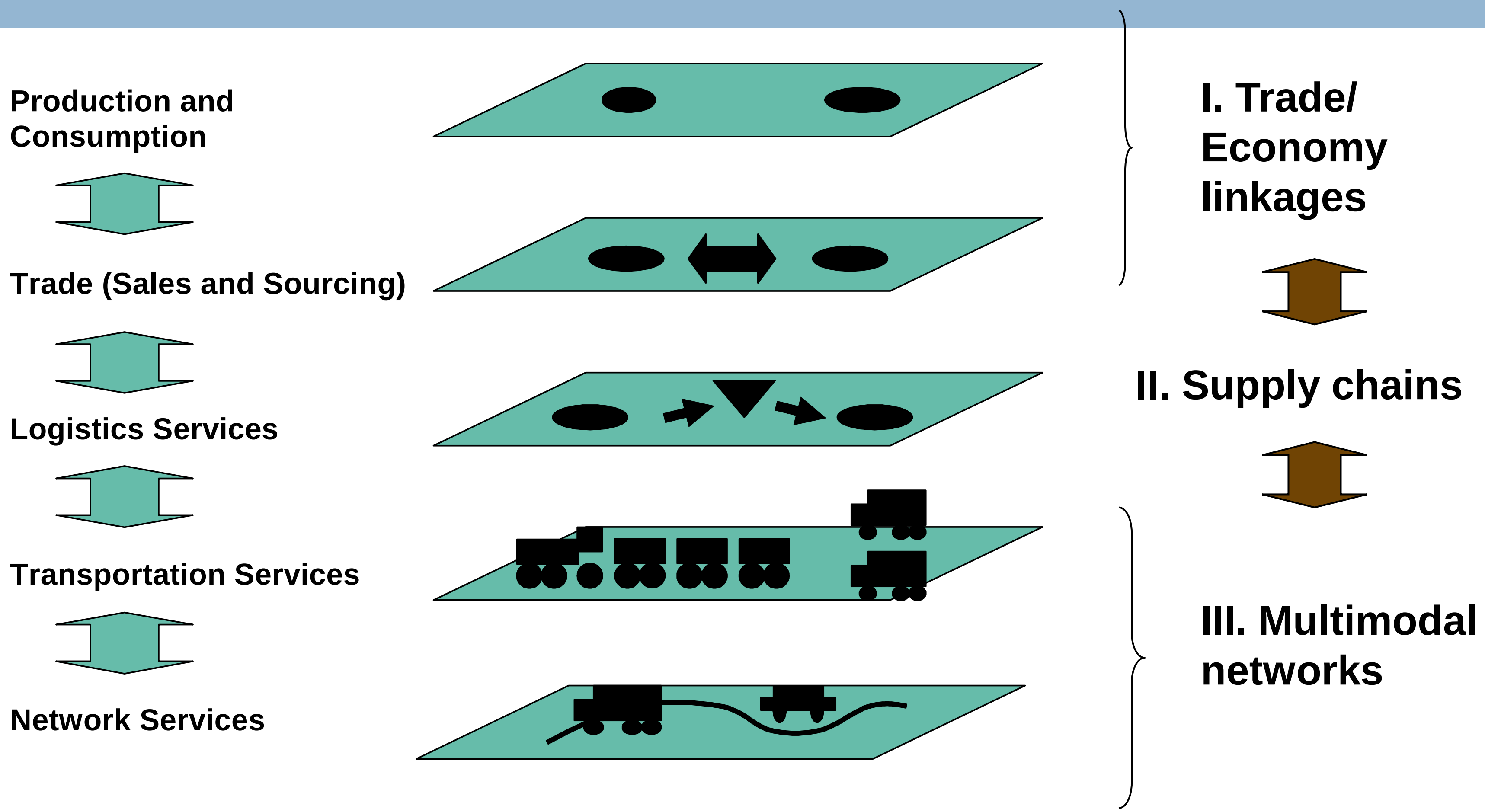


Model taxonomy: 4 stage and beyond



Source: Tavasszy et. al, 2012

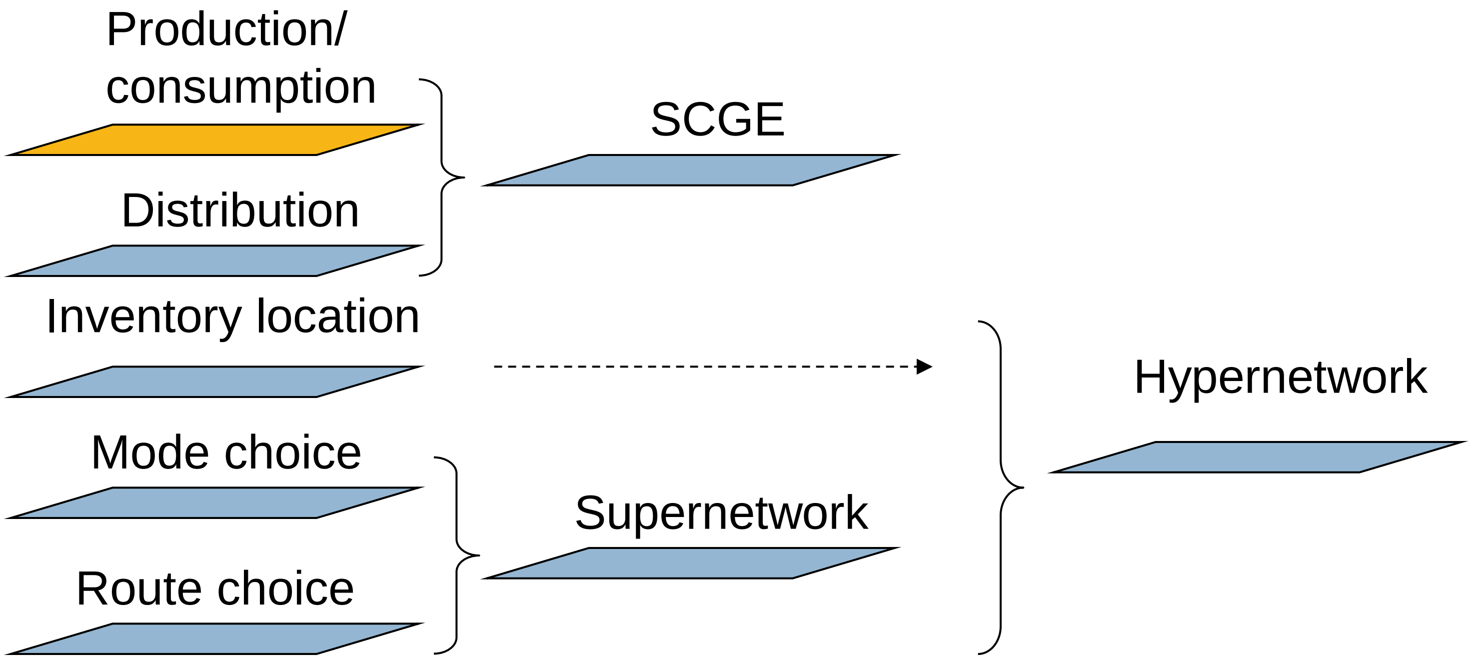
Positioning logistics within the 4 step model



Intermediate conclusion

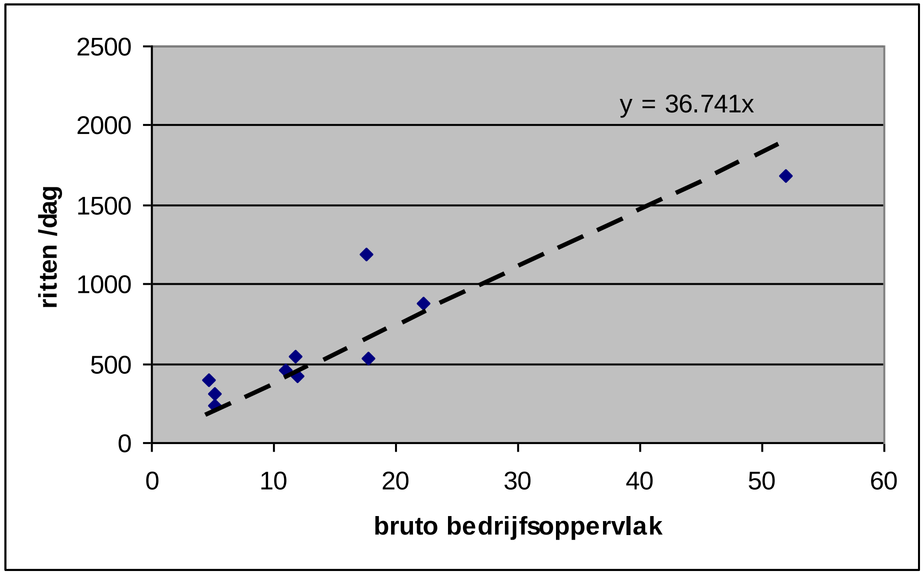
- Freight changes caused by:
  - Changes in the economy
  - Changes in number of tons lifted
  - Changes in the transport performance
  - Changes in traffic performance
- Supply chain considerations: logistics service & total logistics costs
  - Transport
  - Inventory
  - Handling
- 4 step transport demand model needs to be extended to accommodate freight specific issues

Freight generation



Simple freight trip generation models

- Freight generation vs. freight *trip* generation
- Increases with economic activity (business size, # of consumers)
- Depends on sector/ goods type
- Mostly simplified into *linear* model



Zonnenberg, 1989

(*why a problem?*) ← Problem: Just Regression

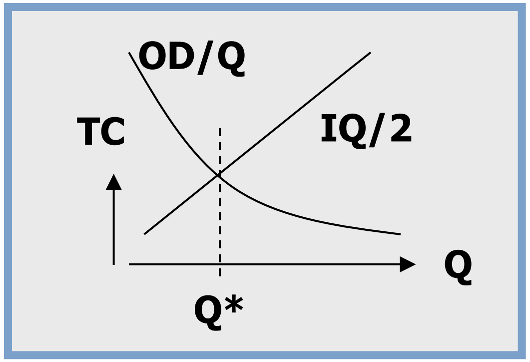
Trip generation & shipment size

Problem Ordering goods from manufacturer: what order size?

EOQ - economic order quantity

Total costs = product costs + ordering costs + inventory costs

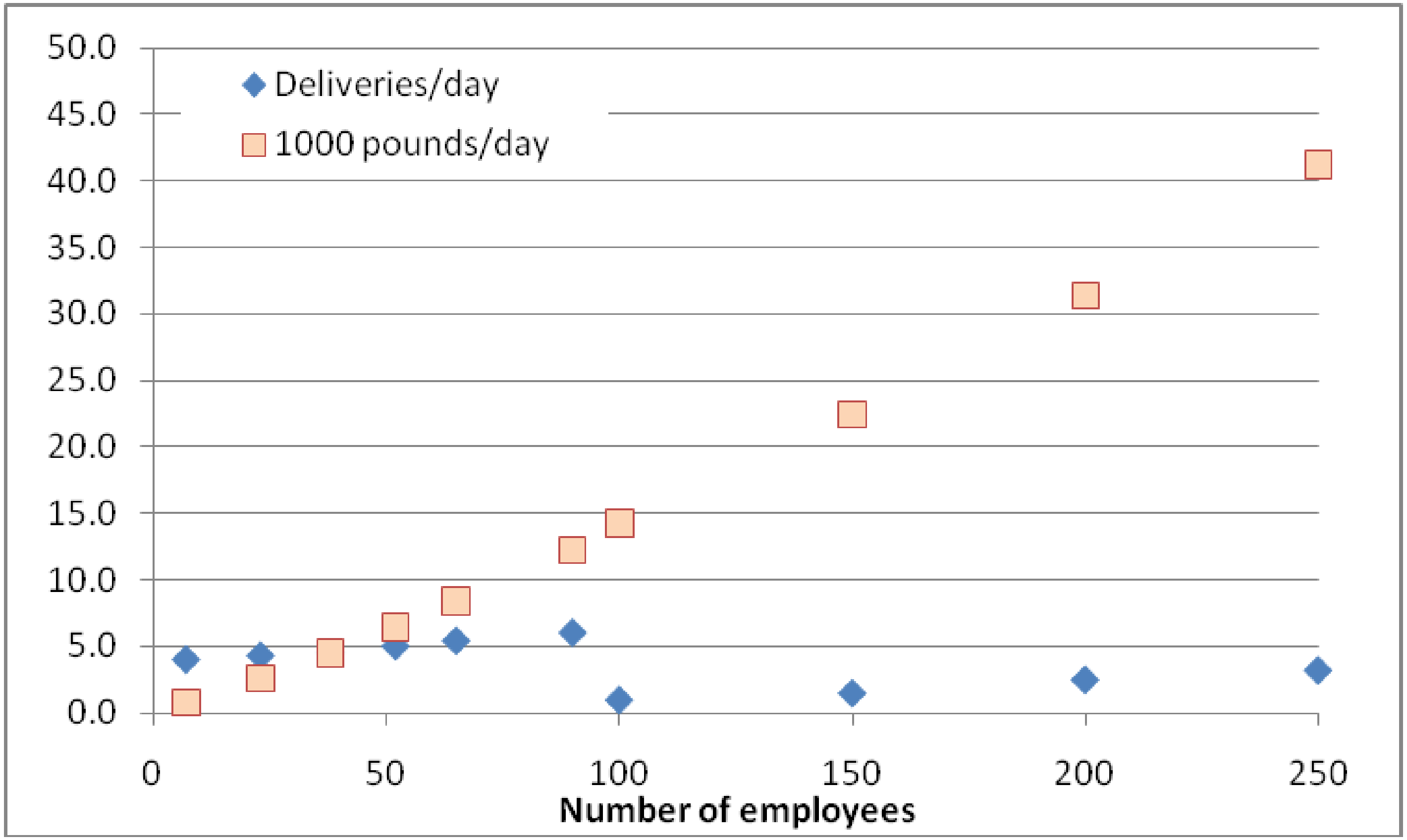
- Price (P) * demand (D)
- Ordering costs /unit (O) * # units (D/Q)
- Inventory cost / unit (I) * average inventory (Q/2)



TC = P*D + O*D/Q + I*Q/2; minimize for shipment size Q

Solution at OD/Q = IQ/2; $Q^* = \sqrt{(2OD/I)}$

Effect of logistics on freight trip generation – or…?



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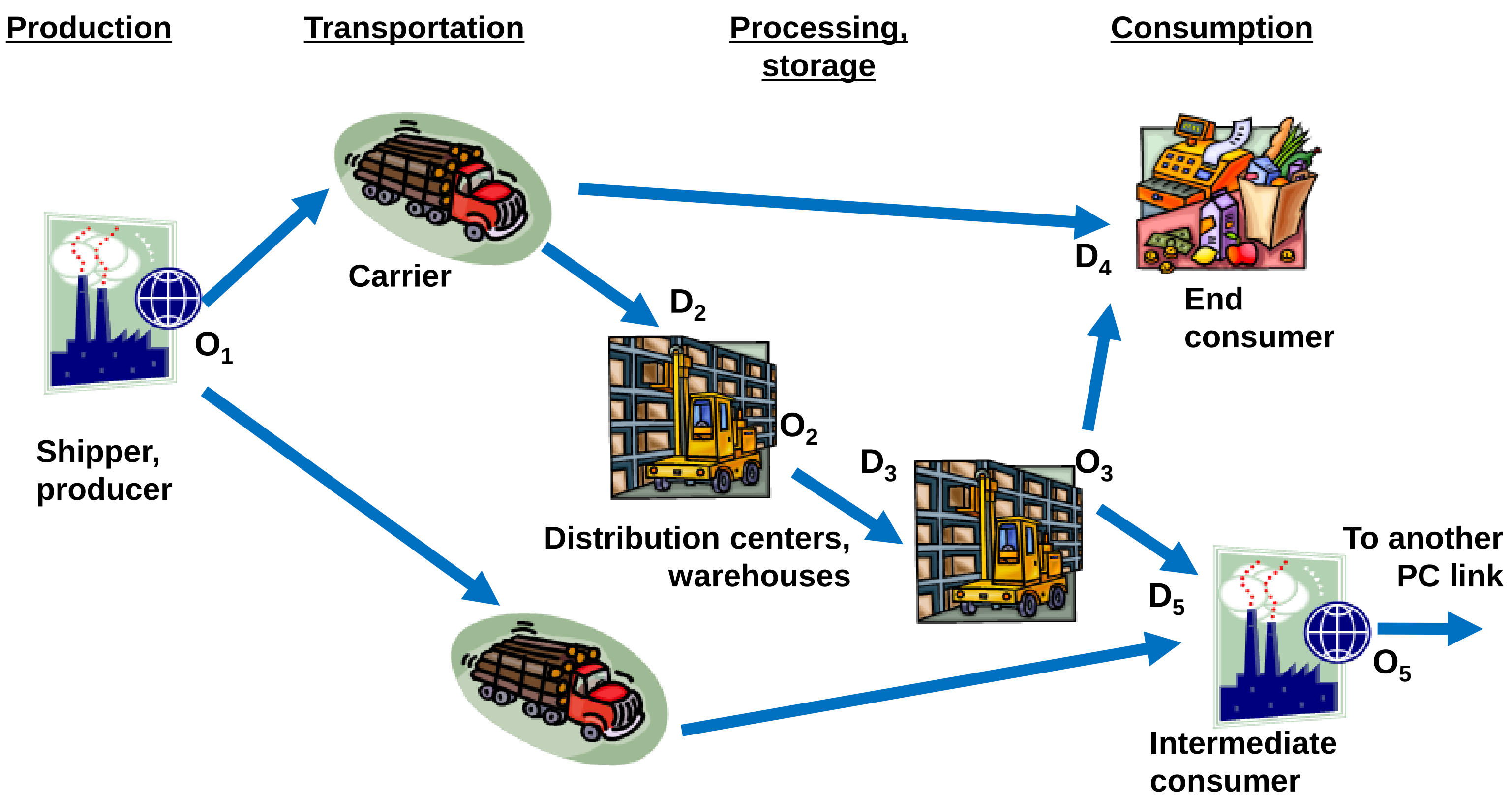
Trip generation vs. production and consumption



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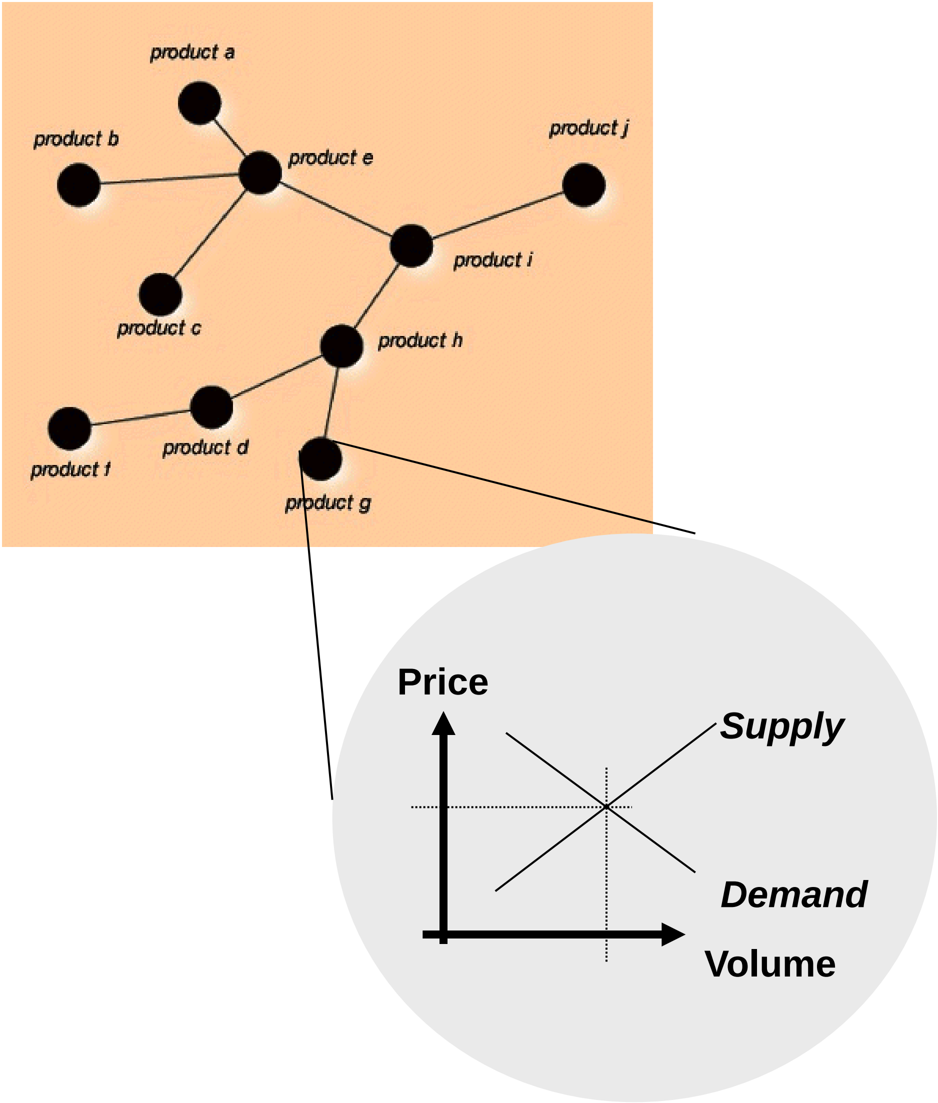
Production and consumption networks

- Input/Output analysis allows us to trace demand effects through sectors as pulled by consumer demand ("final demand")

  => I/O model with fixed relations

- More realistic approach through flexible production functions

  => computable general equilibrium models



Input-Output analysis: basic framework

I/O origin = estimation of GDP for national accounts

(1) Total production **t** = Final demand **y** + Intermediate demand f(**t**)

(2) Intermediate demand = technical coefficient **A** * total production **t**

Assumed fixed!

$\mathbf{t} = \mathbf{y} + \mathbf{A}\mathbf{t} \Rightarrow \mathbf{t} = \mathbf{y}(\mathbf{I}-\mathbf{A})^{-1}$

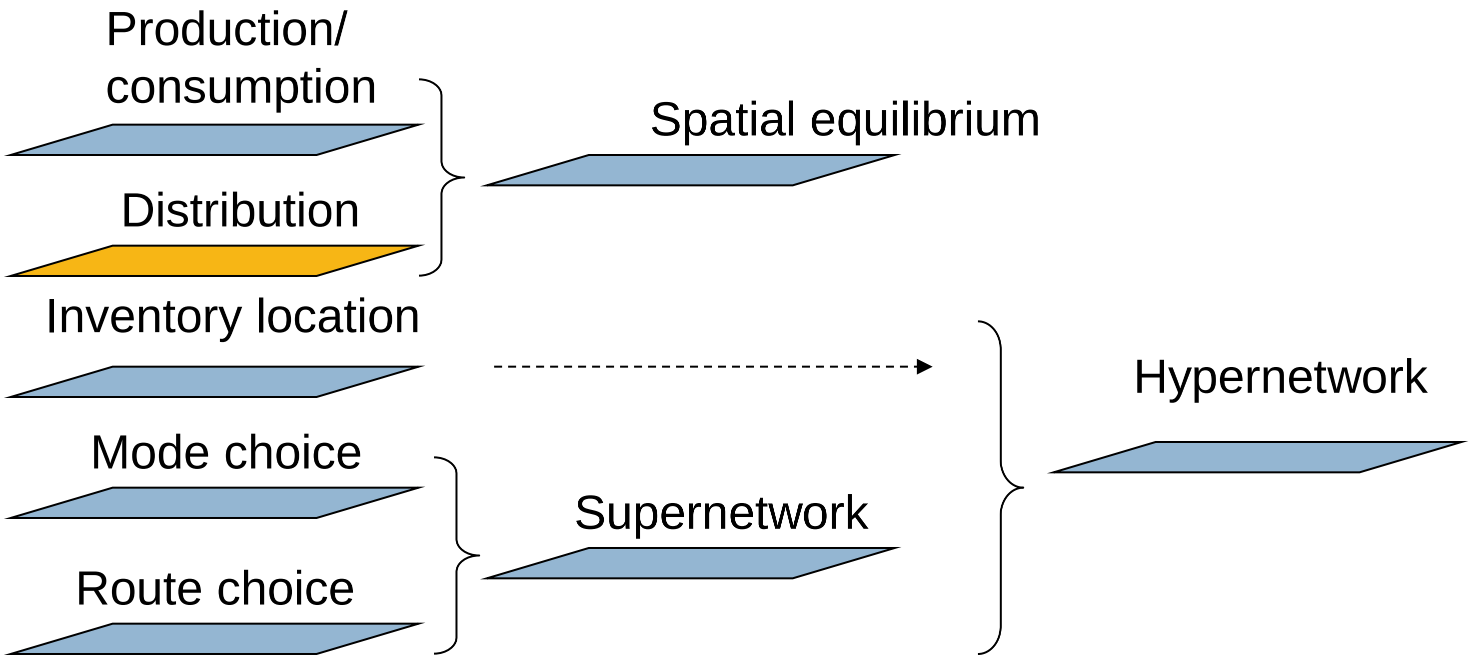
t = vector of total production

y = vector of final demand

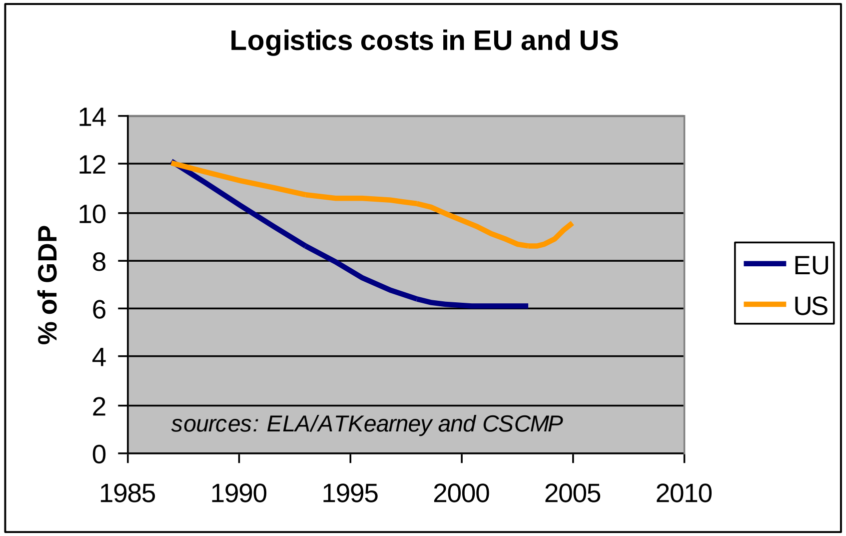
A = matrix of technical coefficients

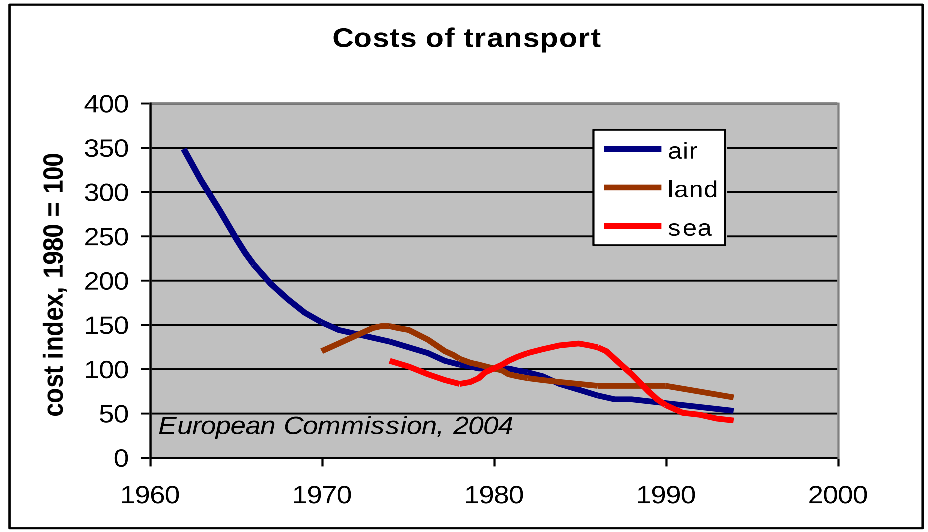
All in *monetary term per year per sector*

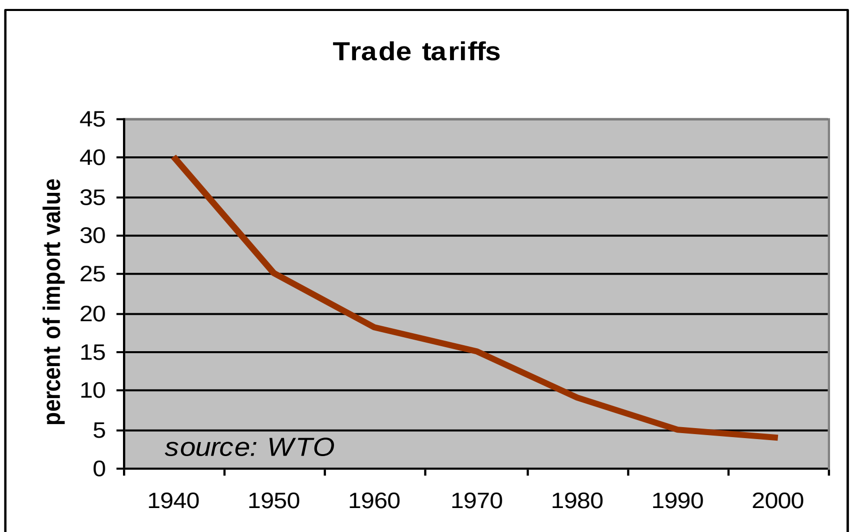
Distribution models

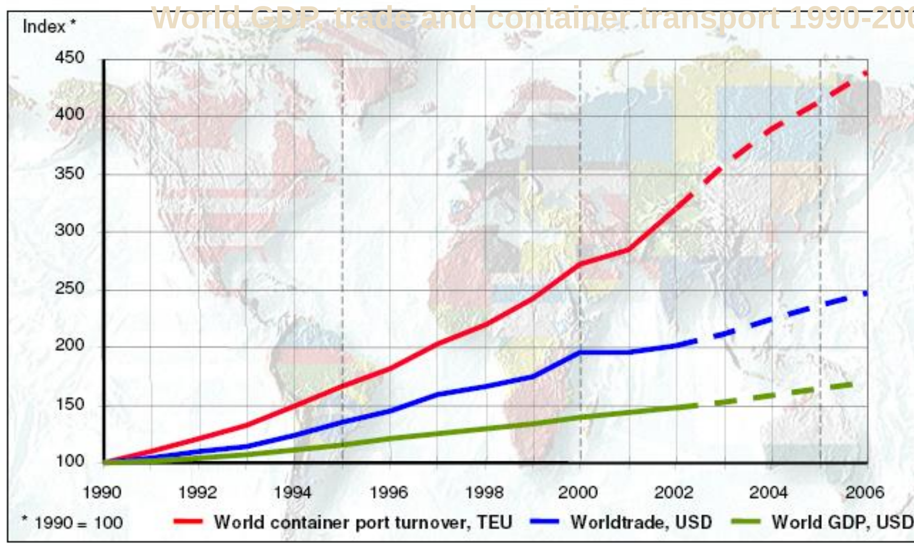


Trade depends also on costs of interaction

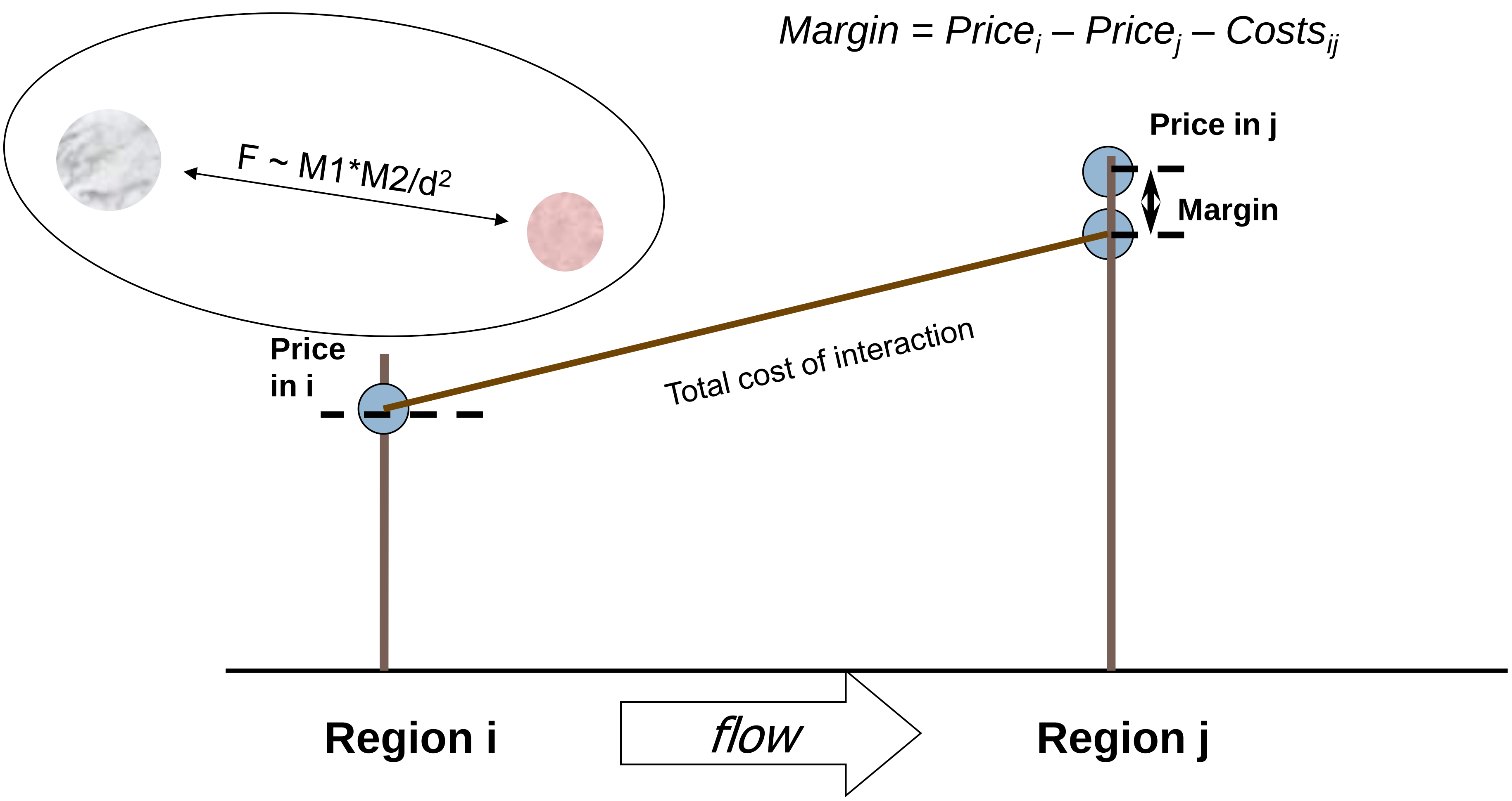




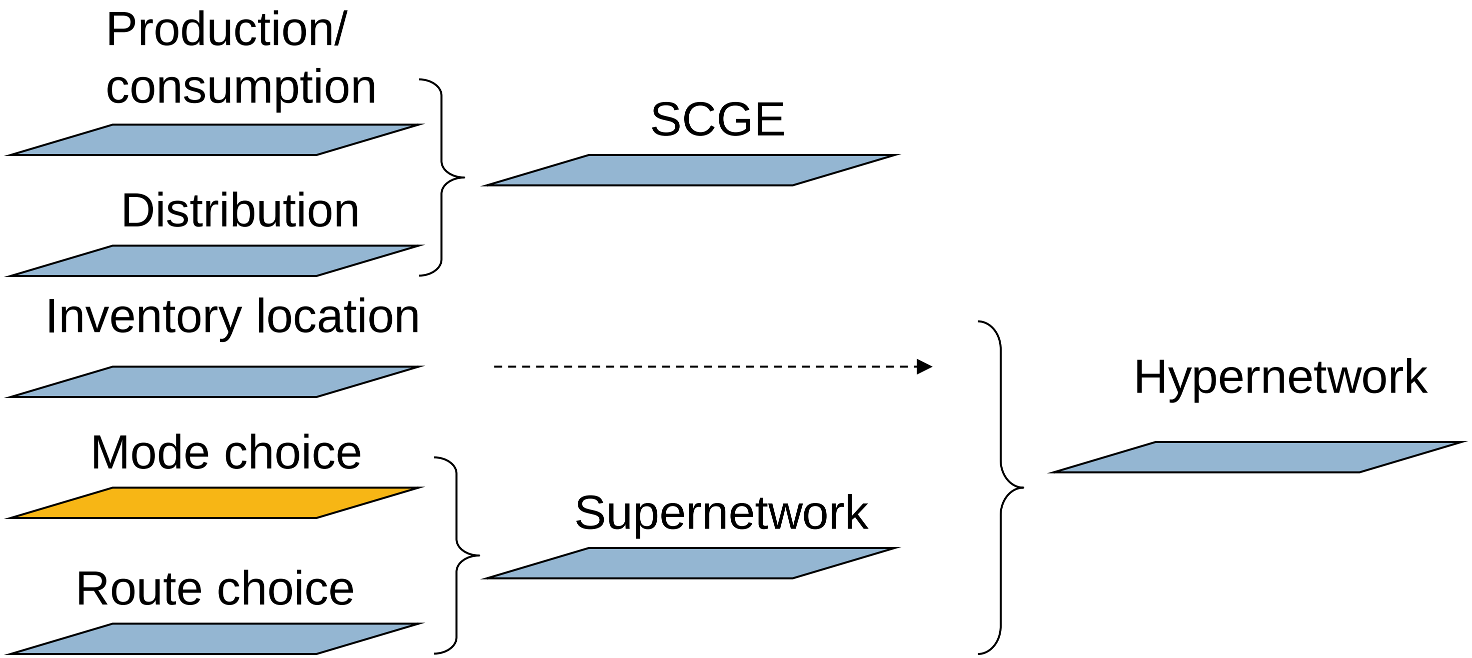




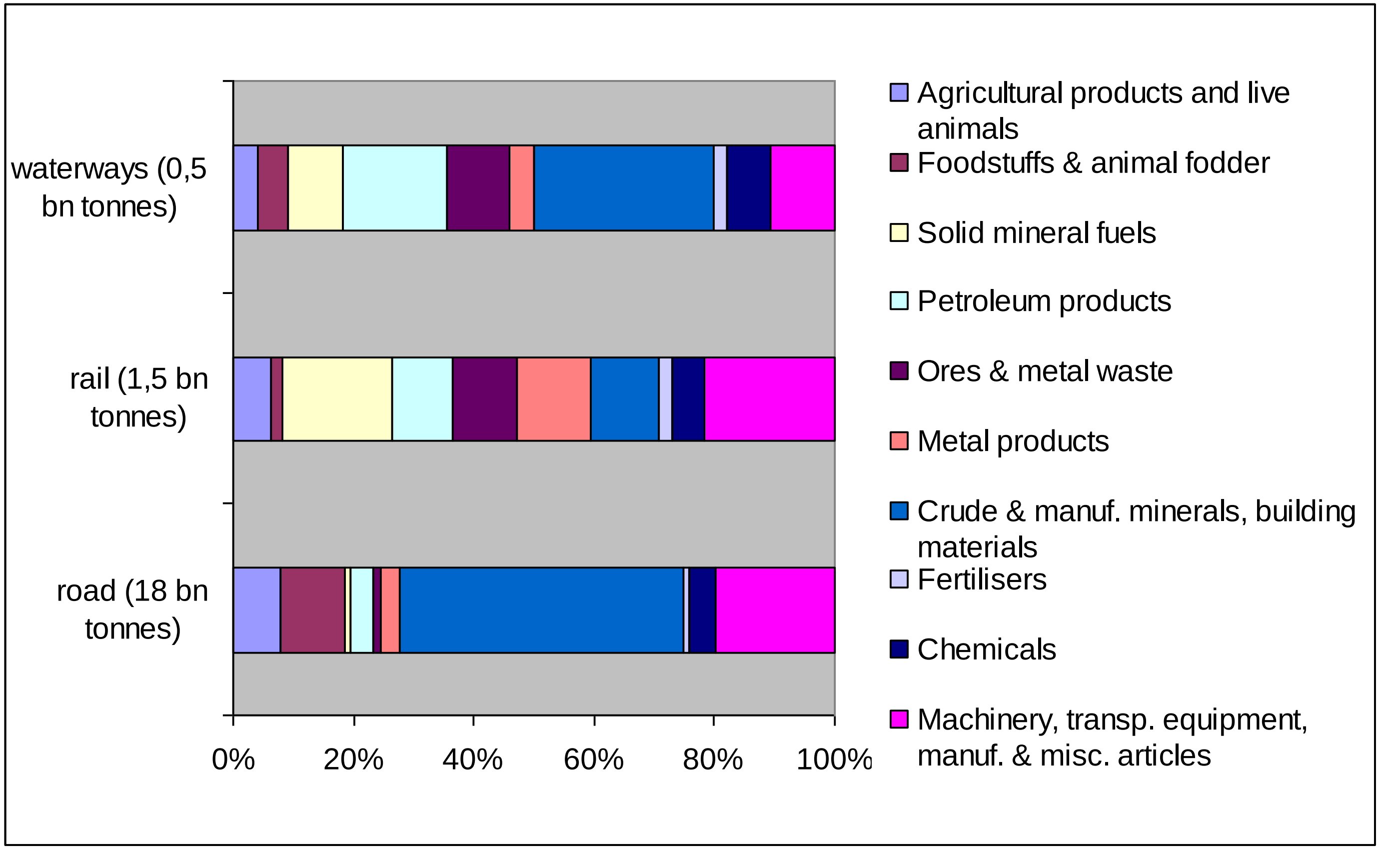
Understanding the gravity model



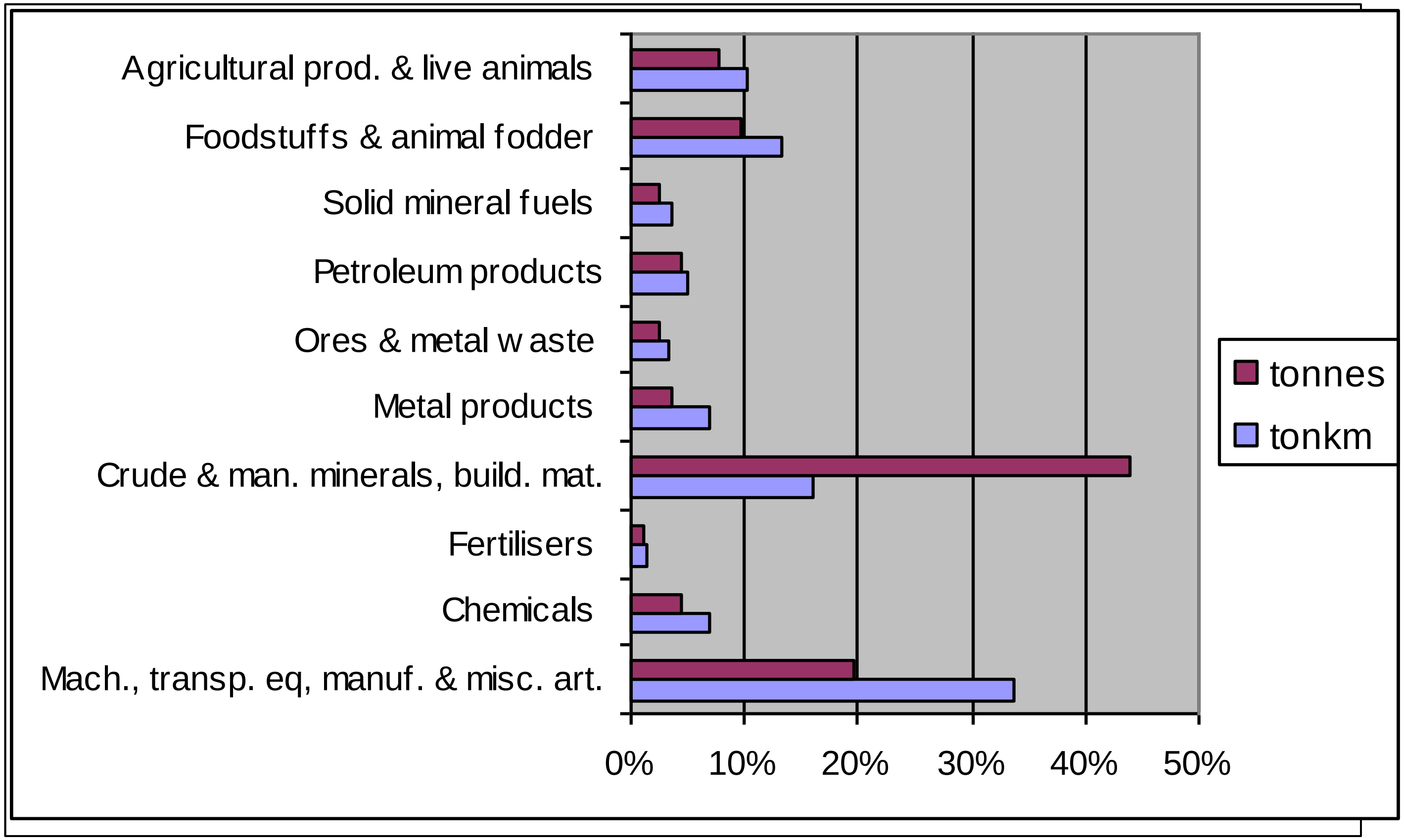
Mode choice models



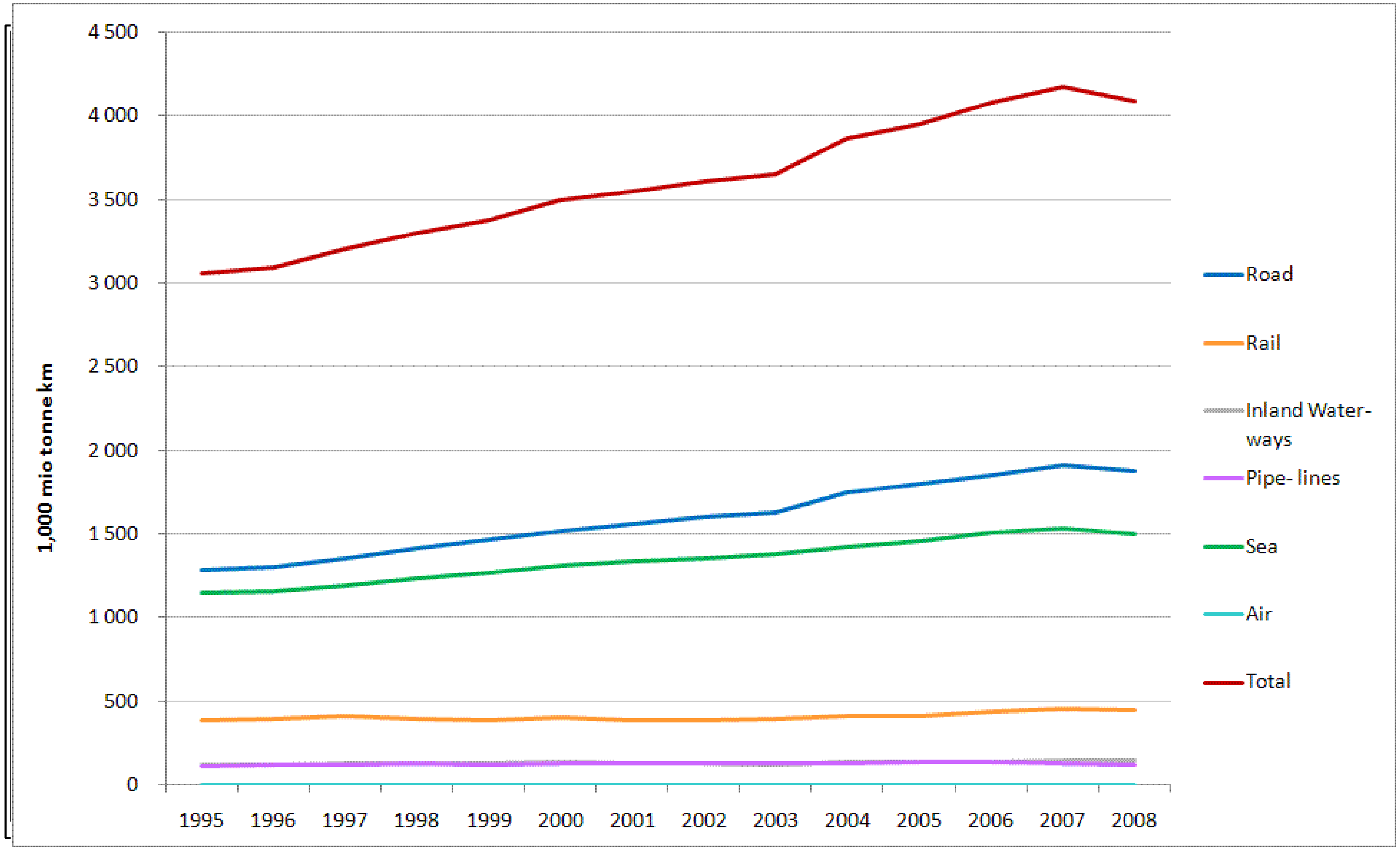
Mode choice: some stats



Mode choice: some stats



Mode choice: some stats



Mode choice models

- Mode attributes (=> *which ones?*)
- Commodity attributes (=> *which ones?*)

- Behavioural models
- Discrete choice models
- Total logistics costs based
  - Include inventory costs
  - In transport
  - At shipper

Table 2.1: Qualitative overview of modal characteristics, taken from (T.E. Platz, 2009)

	Feature	Road	Rail	Inland Waterway
Users				
1	Transport costs per unit	-	+	+
2	Ability to achieve the transport of large volumes	-	+	+
3	Transport speed	+	0	-
4	Network connectivity	+	0	-
5	Predictability of transport process	0	0	+
6	Transport frequency	0	0	0
7	Transport safety	-	+	+
8	Transport security	-	0	+
9	Convenience and flexibility	+	-	-
10	Resistance to extreme weather conditions	-	0	-
11	Limitation of infrastructure capacity, congestion	-	0	+
Governments				
A	Energy-use per ton-km	-	0	+
B	Emission of harmful substances	-	+	0
C	Emission of greenhouse gas	-	+	+
D	Noise, negative effects on ground and water	-	-	+

Legend: + relatively good performance, 0 medium performance, - weak performance.

Q: with all these "-"scores, how come road is so popular?

Mode choice modelling approaches

- Inventory (cost based, all-or-nothing) models

- Behavioral models:

  Minimize out-of-pocket costs (K) ➔ utility maximization $U = -K$

  $V = K_m + \alpha\, T_m$

  Probabilistic approach discrete choice

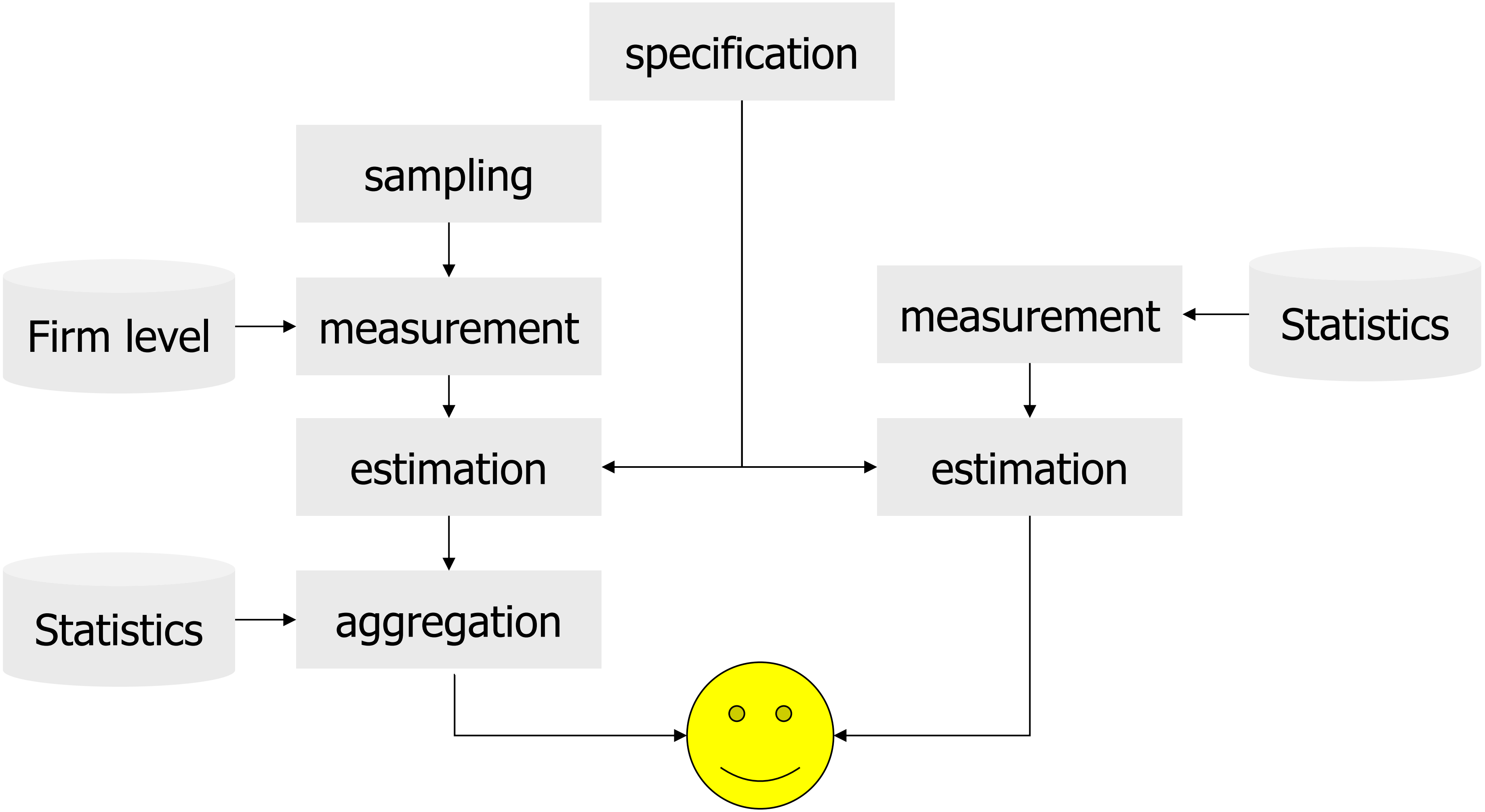
  $U_m = K_m + \alpha\, T_m + \underline{\varepsilon}$

  Deterministic choice & random preferences

  $U_m = K_m + \underline{\alpha}\, T_m$

  } $U_m = K_m + \underline{\alpha}\, T_m + \underline{\varepsilon}$

Disaggregate vs. aggregate models



Operational approaches depend on data used

Aggregate Data

- Land use data
- Trade statistics
- Transport statistics
- Time and costs

Disaggregate data

- Company surveys
- Shipment records
- Goods attributes
- Time and cost data

Combine

- Split aggregate flow data using firm size onto firm level

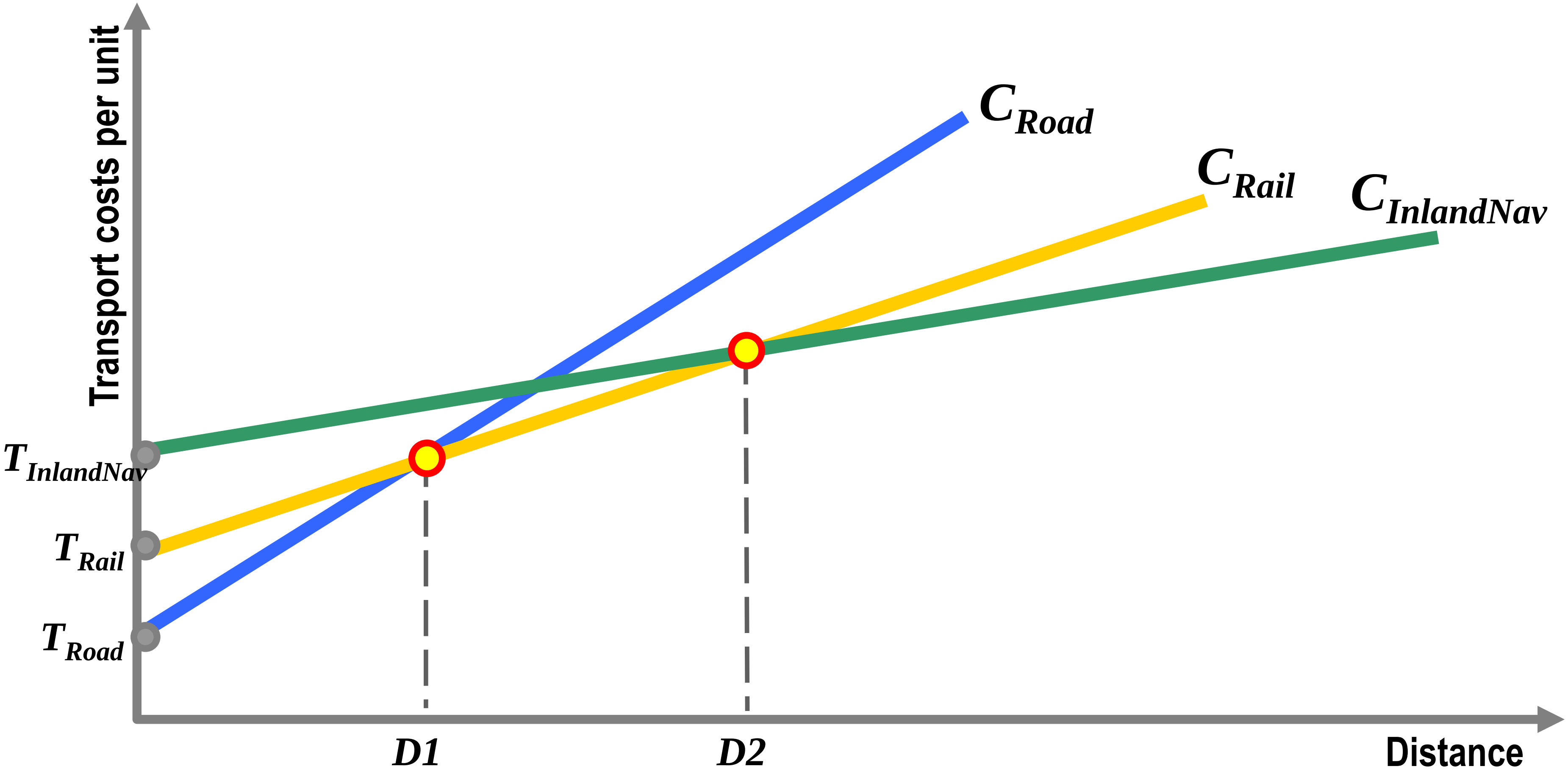
Or

- Make aggregate distributions of goods' attributes

Choice model

- Mode
- Shipment size
- Inventories
- Routing

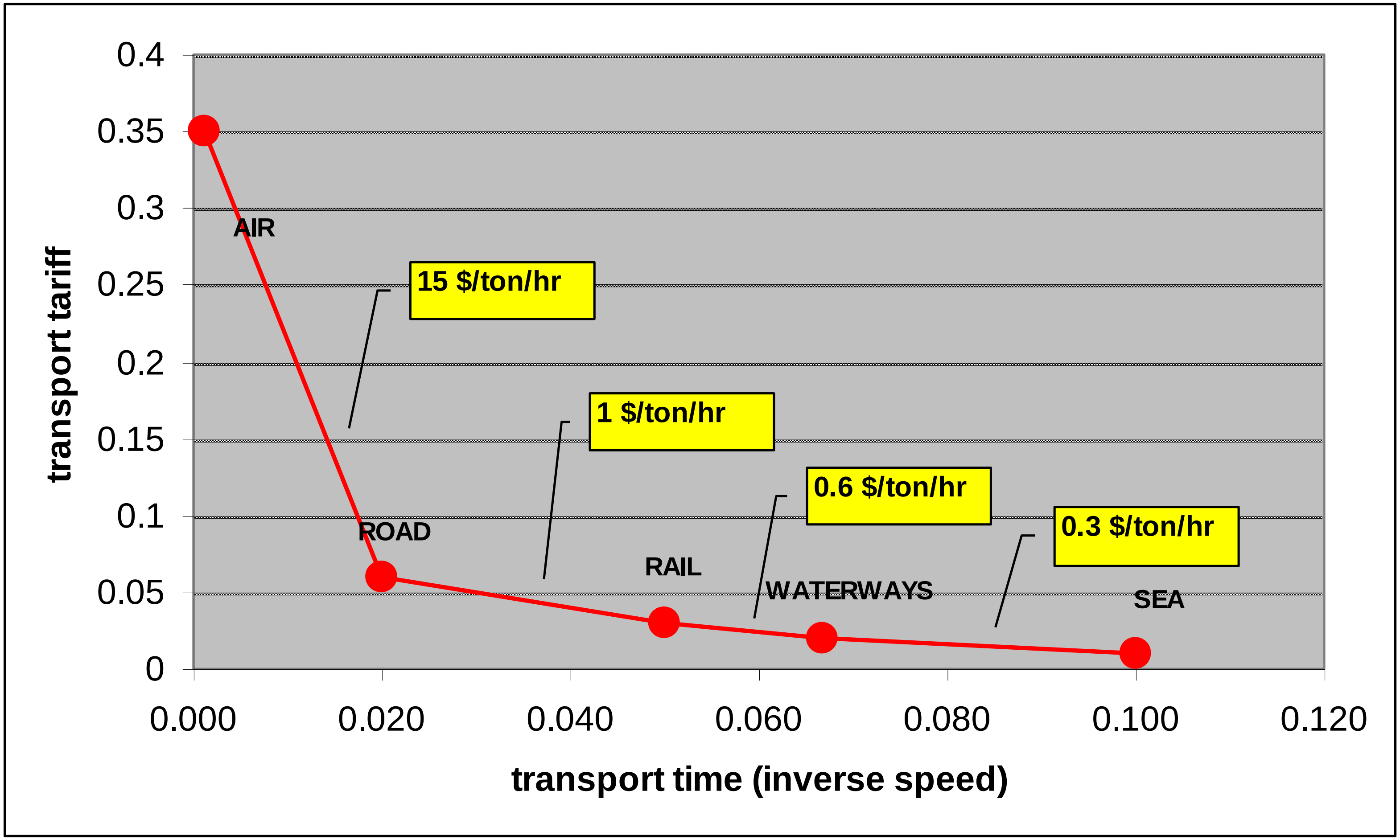
Transport costs



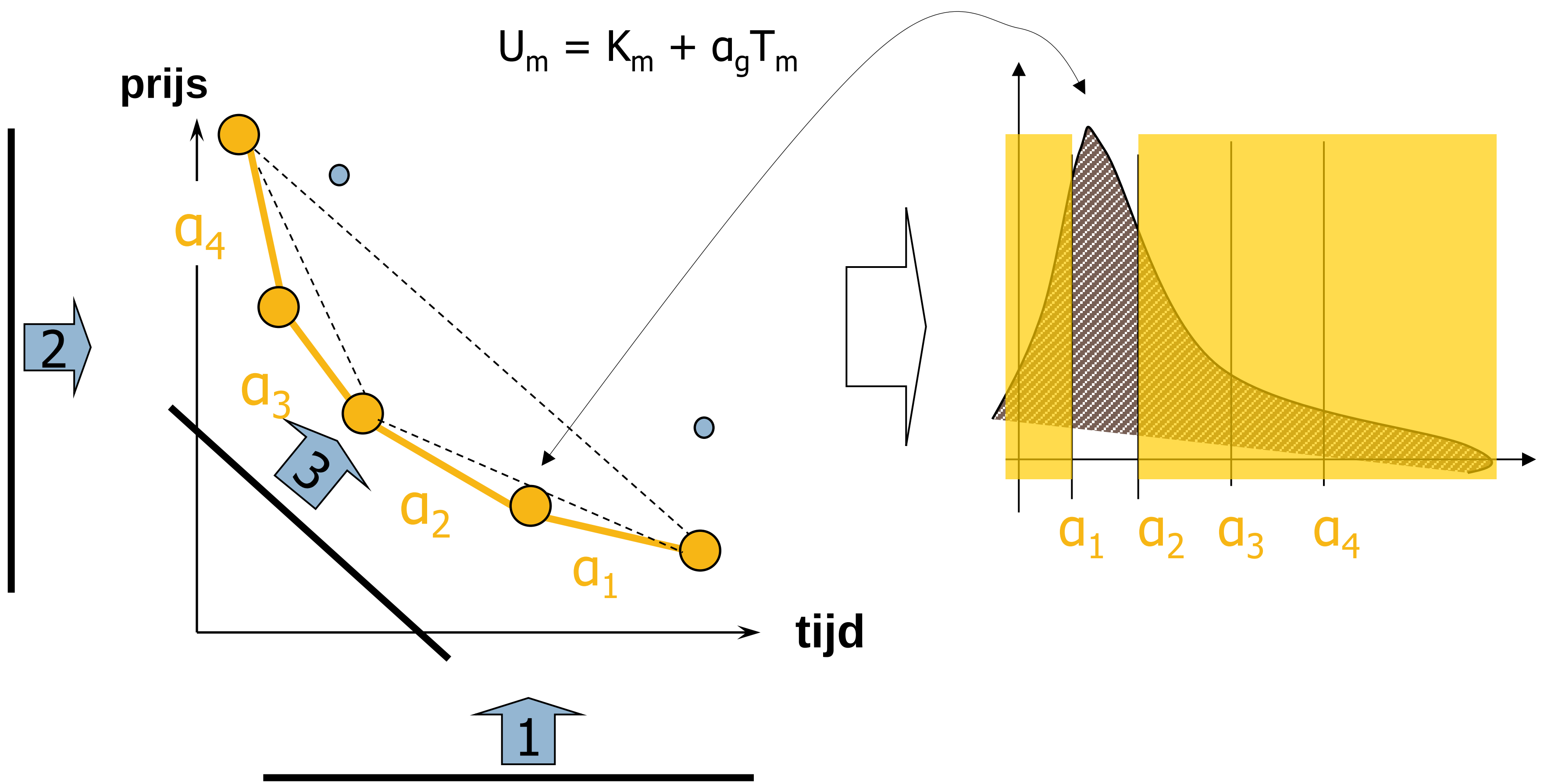
D1: break-even point Road/Rail *D2*: break-even point Rail/Inland navigation

Tx: terminal costs (load/unload costs) *Cx*: cost function mode x

Typical VOT switching values between modes



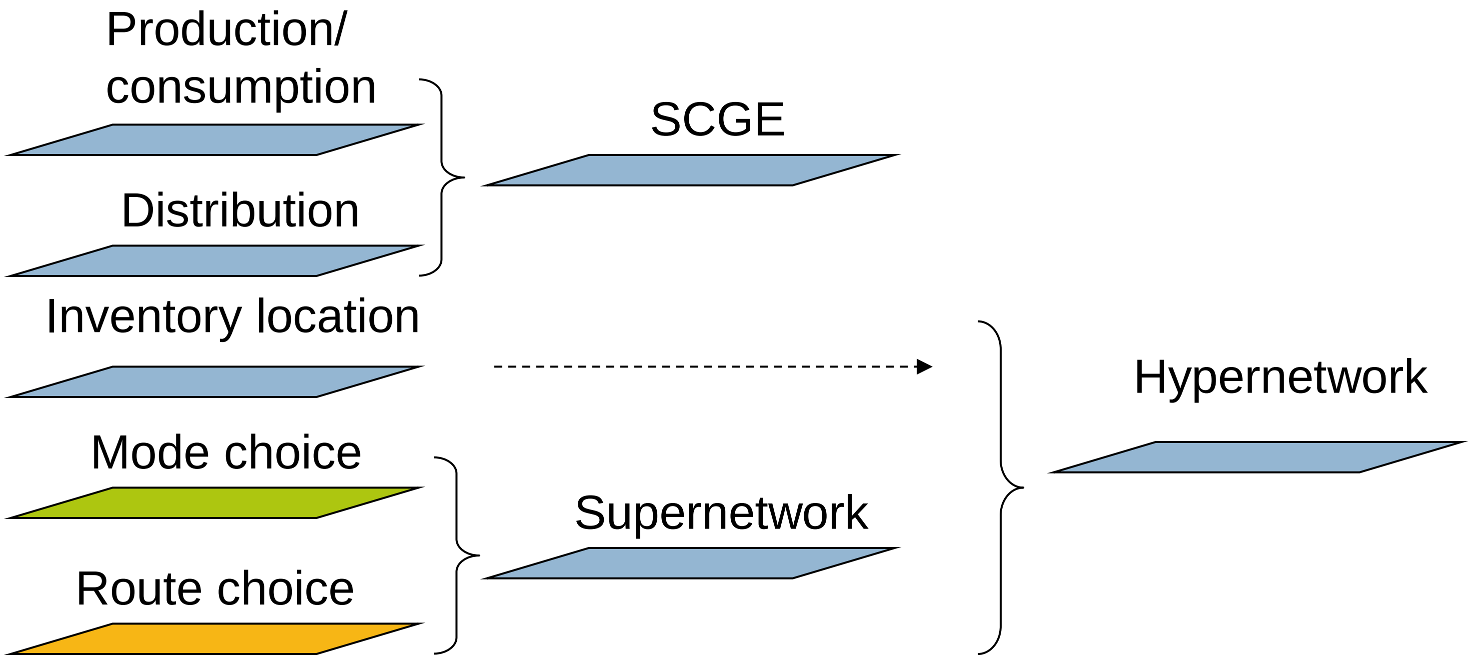
Determination of market shares



Ways to measure the value of time

- Accounts based
  - Factor costs or market prices
- Behavioral analysis (experimental)
  - Aggregate vs. Disaggregate
  - Revealed and Stated Preferences
  - *Between* mode or *Within* mode choice experiments
  - Discrete choice modelling in trade-off situations
  - various alternative choice models
  - other choice situations than mode choice possible
- Disaggregate measurements: *sampling* and *aggregation*
- Aggregate approach: based on *statistics*

Route choice models



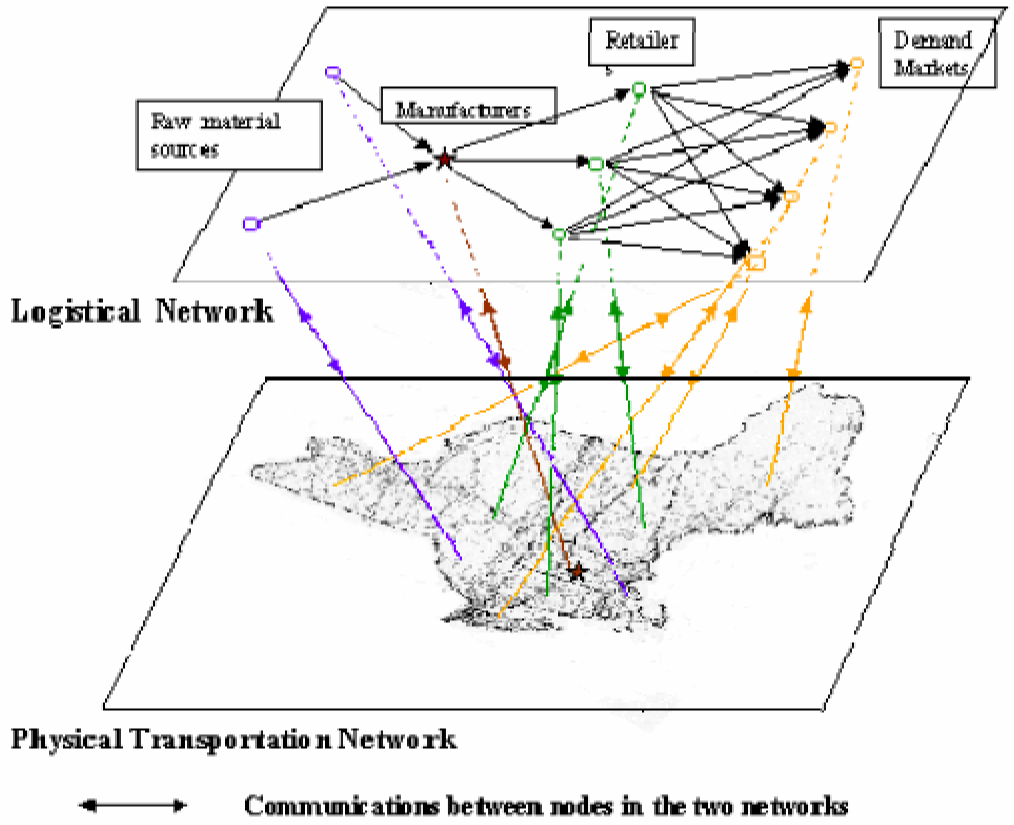
Supernetworks

- History
  - Sheffi (1985) wanted to study network of networks
- Later Nagurney defined supernetworks as follows
  - “the super networks may be thought of as networks that are above and beyond existing networks, which consist of nodes, links, and flows, with nodes corresponding to locations in space, links to connections in the form of roads, cables, etc., and flows to vehicles, data, etc.”

Supernetworks

- Supernetworks have at least one of the features
  - Network of networks
  - Multi-tiered
  - Multi-level
  - Multi-mode network flows
  - Congestion
  - Alternative behavior of users of the network
  - Multi-criteria

Supernetworks Illustration



Supernetwork analogies

- Supernetwork concept has a wide range of applications and only a small part of those applications has been explored thus far.
- Some specific applications of supernetworks are: supernetworks consisting of
  - social networks interacting with supply chain networks,
  - financial networks, and
  - knowledge supernetworks

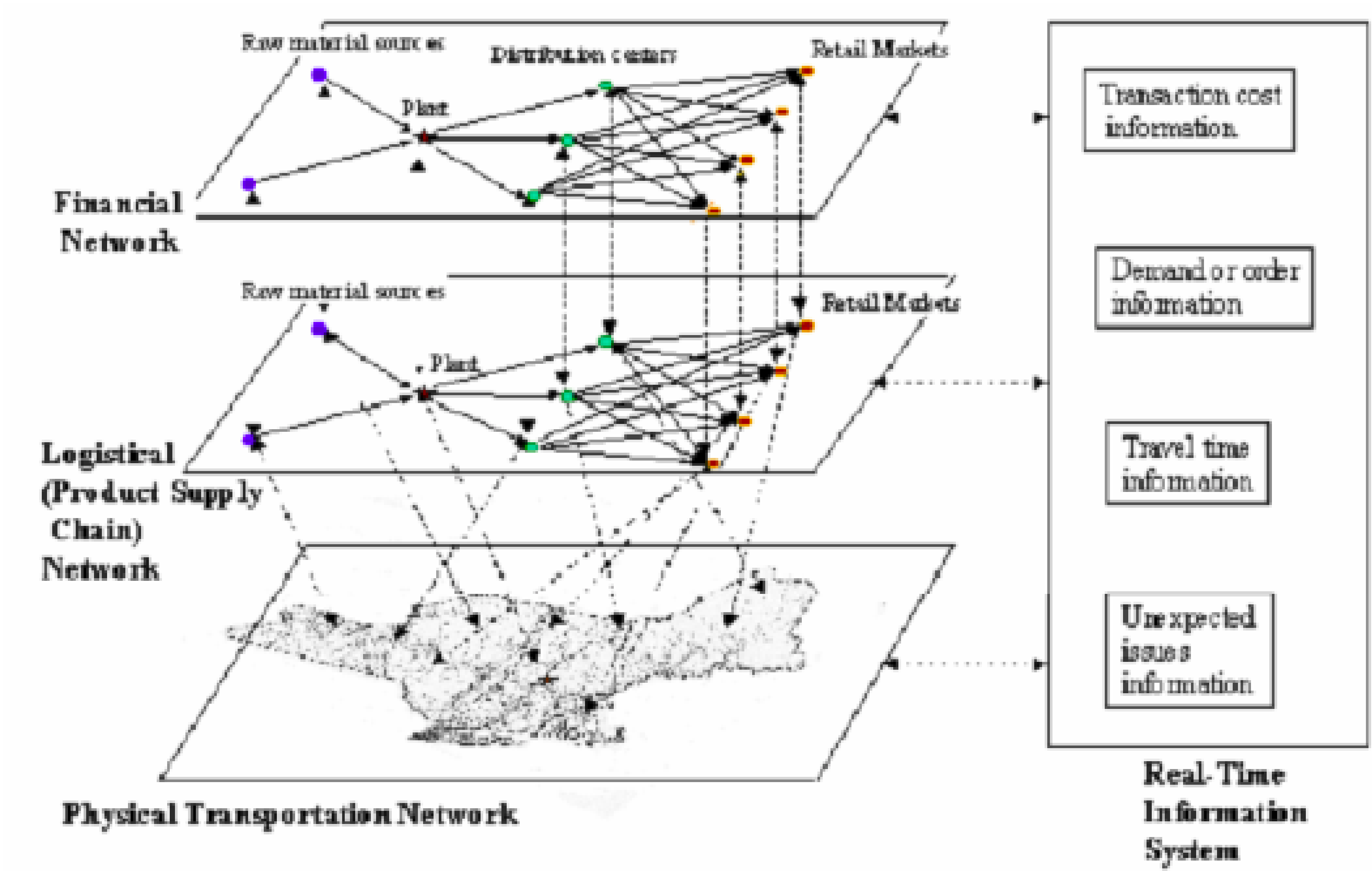
Supernetwork equillibrium

- This framework captures the different interacting networks in one model.
- It allows one to compute optimal solutions under different scenarios and to test how the equilibrium will change when certain cost and benefit functions are changed.

Supernetwork interdependencies

- Supernetworks can also be explained as systems of systems. It allows one to compute optimal solutions under different scenarios and to test how the equilibrium will change when certain cost and benefit functions are changed.
  - Operational independence
  - Managerial independence
  - Geographic distribution
  - Heterogeneity
  - Evolutionary and emergent behaviors

Freight and Supernetworks



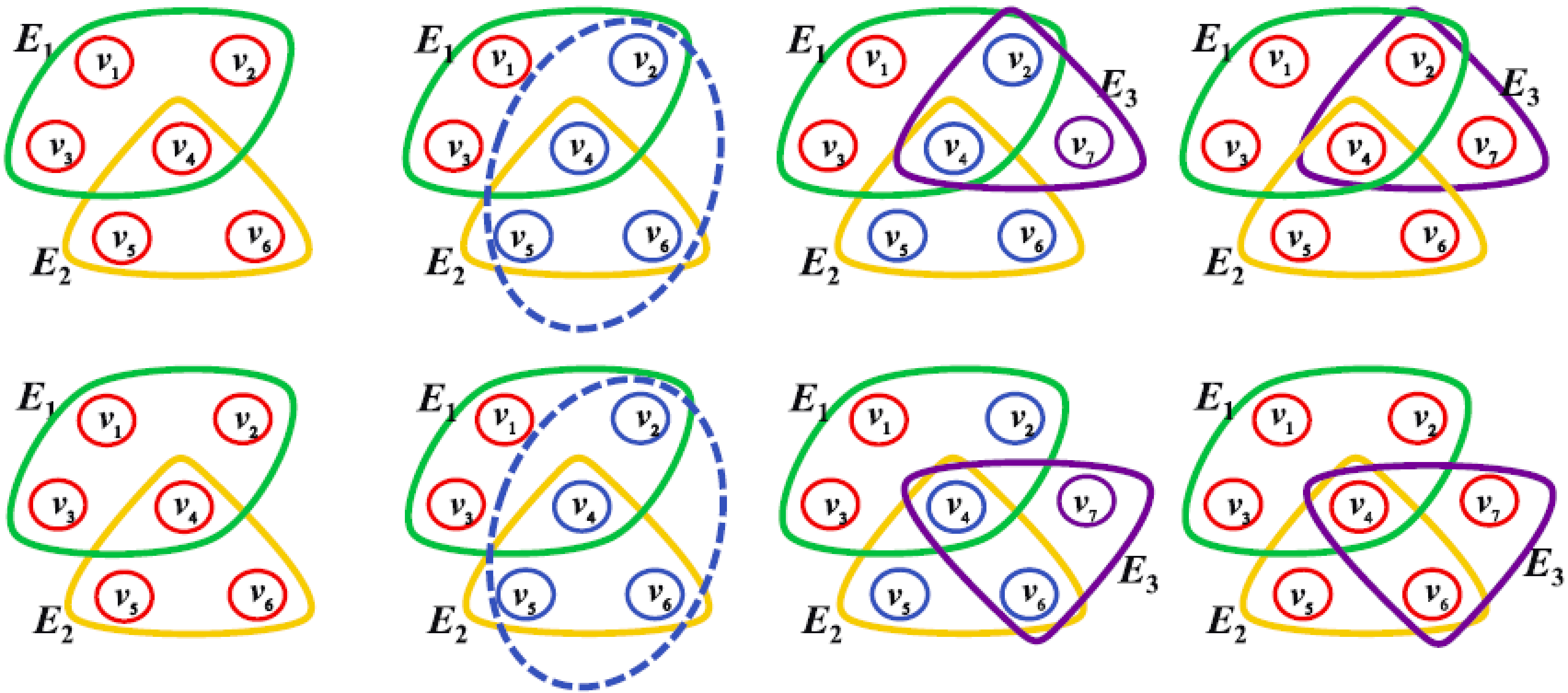
Methods for Supernetworks

- Network theory;
- Optimization theory;
- Game theory;
- Variational inequality theory;
- Projected dynamical systems theory;
- Network visualization tools

Hypernetworks

- In a hyperedge can contain more than two nodes.
- Thus, it is useful to represent the collaboration network as a hypernetwork.

Liu et al. (2014)

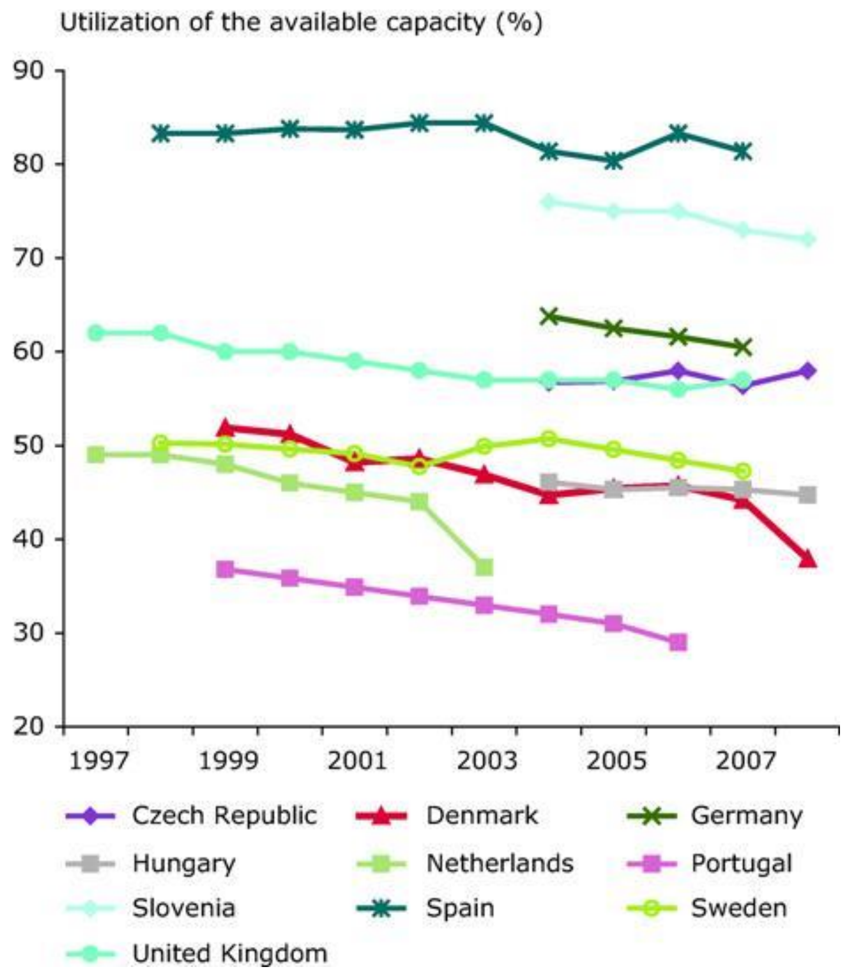


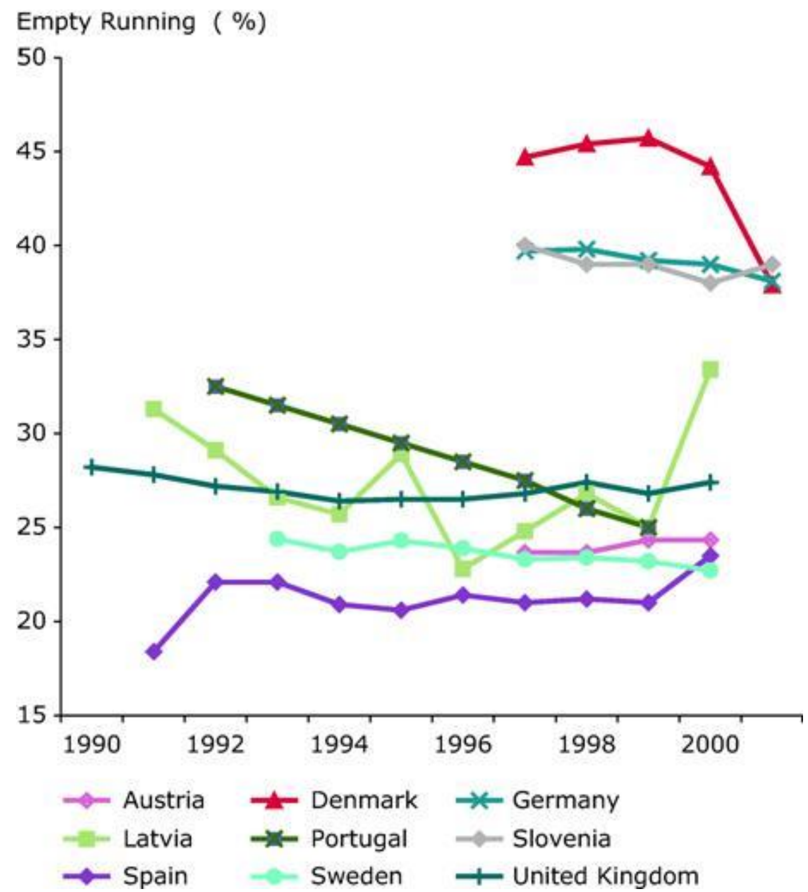
Route choice for freight

- Most freight models apply similar route choice techniques as in passenger transport (e.g. Dijkstra algorithm)

- Specific concerns for freight:
  - Road: round trips (TSP); restrictions: weight & size regulations
  - Rail: train paths; restrictions: gauge width; voltage; priorities
  - Waterways: waterways sizes & ship classes
  - Sea: shipping line & feeder services; restrictions: port depth
  - Air: hub & spoke networks; flight level 0 (trucking)

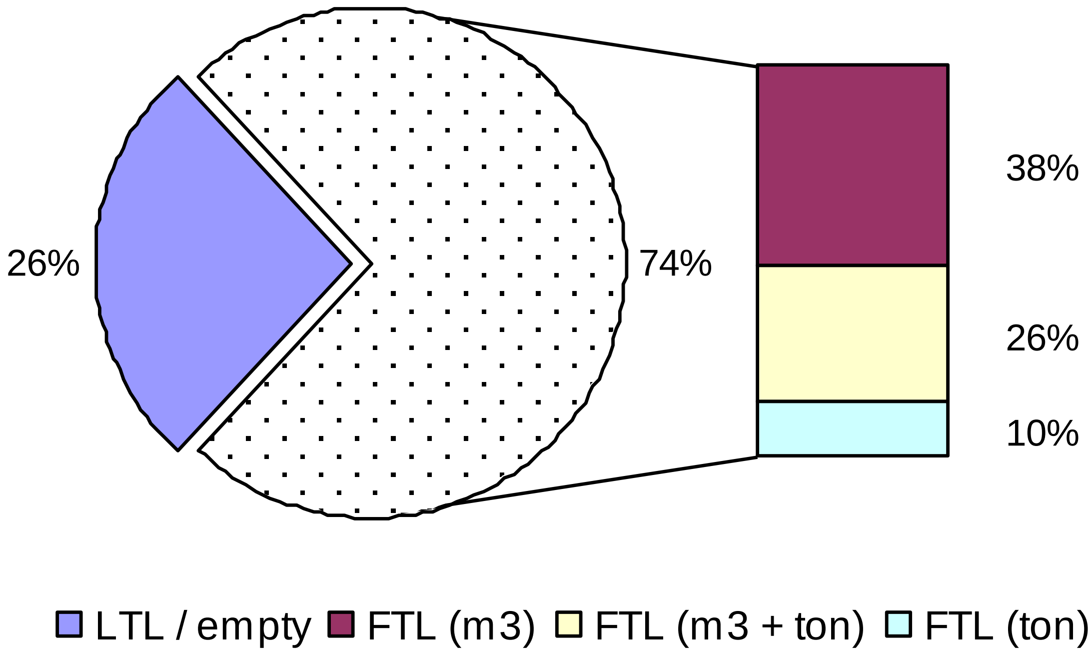
Dynamics in efficiency



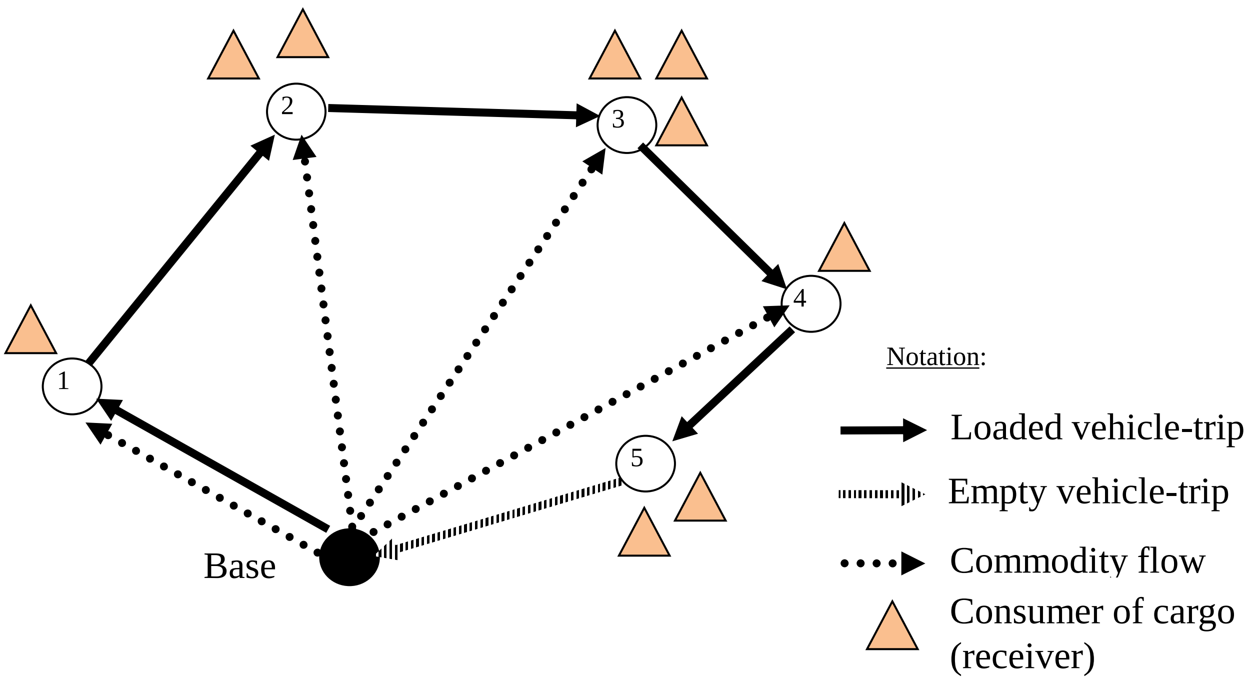


A note on the degree of loading

Survey A10-20/RN10 (F): volume and weight of equal importance (Combes, Univ Paris-Est, 2010)

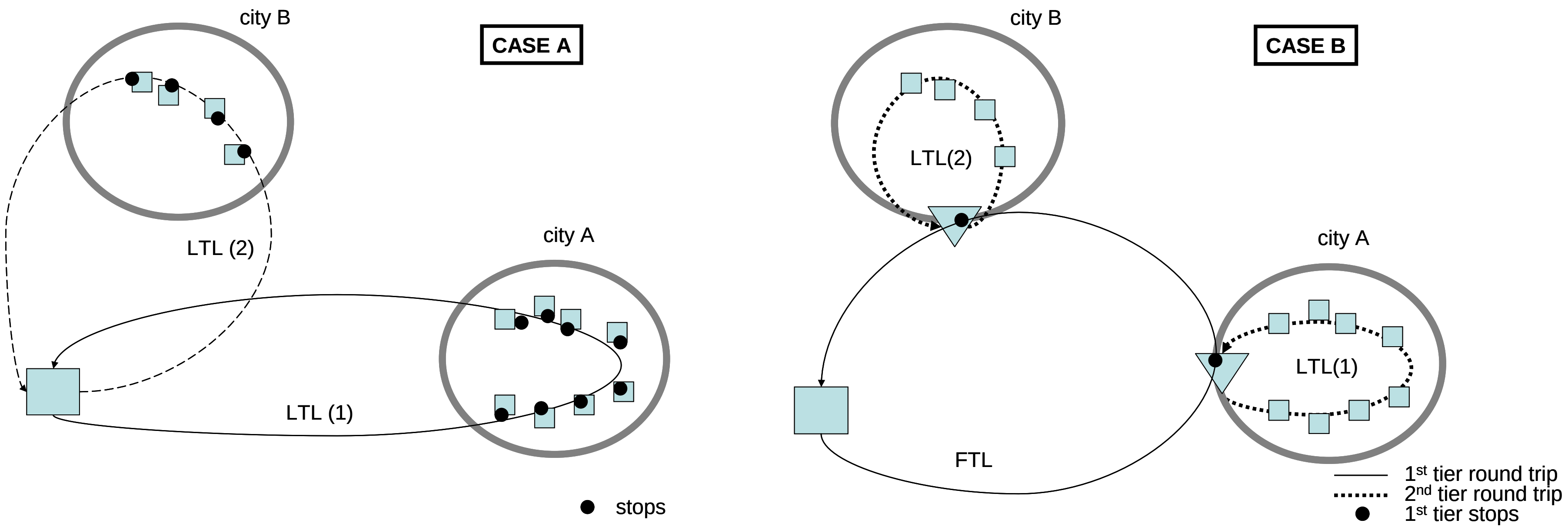


Simple route vs. round trips



NCFRP 25. Holguin Veras et al, 2010

Transport reorganization: routing



Assignment approaches

- Equillibrium approaches as in passenger transportation
- Preloading
- Multiclass assignment