

# THE CHOICE OF SHIPMENT SIZE IN FREIGHT TRANSPORT

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# INTRODUCTION

- Context
- Problem Statement
- General Objectives
- Thesis Outline
- Presentation Outline

# Context

## Introduction

I Systems Analysis  
II Modelling Framework  
III Costs Representation  
IV Logistic Imperatives  
Conclusion

## Context

Problem Statement  
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Presentation Outline

- Classic freight transport models are based on the four stages representation. It details:
  1. The location decision
  2. The supplier-customer decision
  3. The mode choice
  4. The route choice
- This representation has shortcomings:
  - ▣ The definition of origins and destinations is ambiguous
  - ▣ The discrete nature of freight transport operations is absent

# Problem statement

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### Problem Statement

General Objectives  
Thesis Outline  
Presentation Outline

- The purpose of this work is to investigate *the difficulties and potential benefits of representing explicitly the choice of shipment size in spatialised freight transport models*

# General Objectives

## Introduction

I Systems Analysis  
II Modelling Framework  
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## General Objectives

Thesis Outline

Presentation Outline

- Selected requirements
  - A representation of the freight transport system
  - A widely valid model of choice of shipment size
  - A reasonable complexity
- Selected perspectives
  - Logistic-based modelling of shippers' preferences
  - Simultaneous use of two modes for a given commodity flow

# Thesis Outline

## Introduction

I Systems Analysis  
II Modelling Framework  
III Costs Representation  
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## Thesis Outline

Presentation Outline

- **Part I: Framework and bibliography**
  - Chapter 1: Advances in freight transport modelling
  - Chapter 2: Logistic issues and their modelling
  
- **Part II: Systems analysis and metrology**
  - Chapter 3: Freight transport systemic representation
  - Chapter 4: Road-side survey protocol improvement
  - Chapter 5: Econometric validity of the EOQ model
  
- **Part III: Microeconomic analysis**
  - Chapter 6: Shipment size and freight rates
  - Chapter 7: Logistic imperatives and mode choice

# Presentation Outline

## Introduction

I Systems Analysis  
II Modelling Framework  
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## Presentation Outline

- Introduction
- Part I: Systems analysis
- Part II: A simple modelling framework
- Part III: Improving the representation of costs
- Part IV: Logistic imperatives and mode choice
- Conclusion

# Part I : Systems analysis

- Objectives
- Freight transport supply
- Freight transport demand
- Full representation

*Based on Chapters 1, 2 and 3*



# Objectives

## What should be represented

- A representation of the freight transport system should distinguish:
  - ▣ What is exchanged on the freight transport market
  - ▣ The formation of freight transport demand
  - ▣ The formation of freight transport supply
- This representation should be consistent with existing models

Introduction

I Systems Analysis

II Modelling Framework

III Costs Representation

IV Logistic Imperatives

Conclusion

Objectives

Decision Unit

Supply

Demand

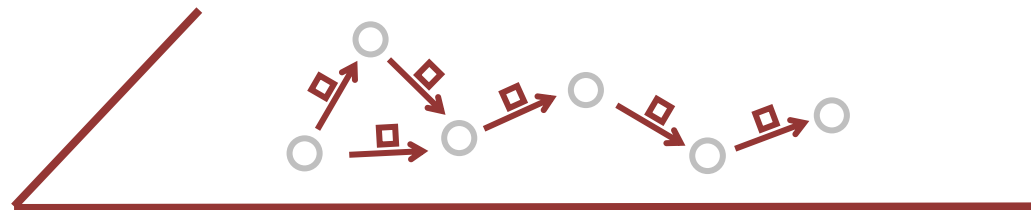
Full Representation

# The decision unit

- **Shipment** definition (adapted from Guilbault *et al.* 2006):

*« a given amount of freight of a given type, handed over at given place and time, by a unique shipper in order to be carried as a whole towards a given, unique receiver »*

- What is exchanged on the freight transport market: **door-to-door shipment transport operations**



# Freight transport supply (1/2)

## Principles

Introduction  
I Systems Analysis  
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III Costs Representation  
IV Logistic Imperatives  
Conclusion

Objectives  
Decision Unit  
Supply  
Demand  
Full Representation

- Carriers produce door-to-door shipment transport operations with given characteristics
  - ▣ Date, place, travel duration, cost, reliability, etc.
- These operations most often combine **transshipments**
- General characteristics of the freight transport technology:
  - ▣ Economies of **scale**
  - ▣ Economies of **scope**

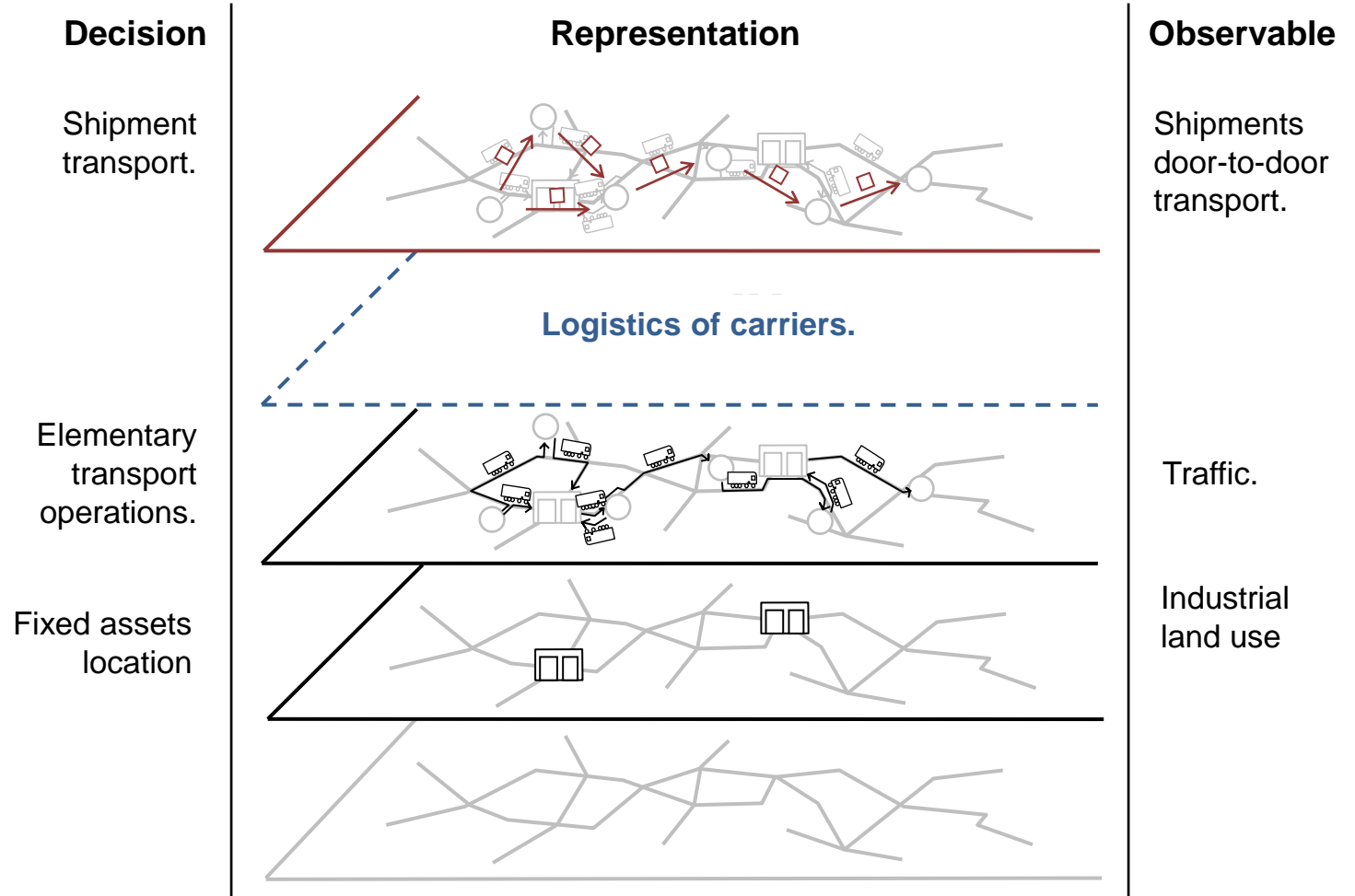
# Freight transport supply (2/2)

## Representation

- Introduction
- I Systems Analysis
- II Modelling Framework
- III Costs Representation
- IV Logistic Imperatives
- Conclusion

- Objectives
- Decision Unit
- Supply
- Demand
- Full Representation



# Freight transport demand (1/2)

## Principles

Introduction  
I Systems Analysis  
II Modelling Framework  
III Costs Representation  
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Conclusion

Objectives  
Decision Unit  
Supply  
Demand  
Full Representation

- Shippers consume freight transport operations of given characteristics
  - ▣ Date, place, travel duration, cost, reliability, etc. (and not mode or route)
- The preferences of shippers derive from those of their customers: goods provide utility to customers if they are **available**.
- Logistic of shippers:
  - « *The art and manner to provide a given commodity at the **right time, right place**, at the lowest cost and with the best quality* »

Definition from ASLOG, French Association for Logistic

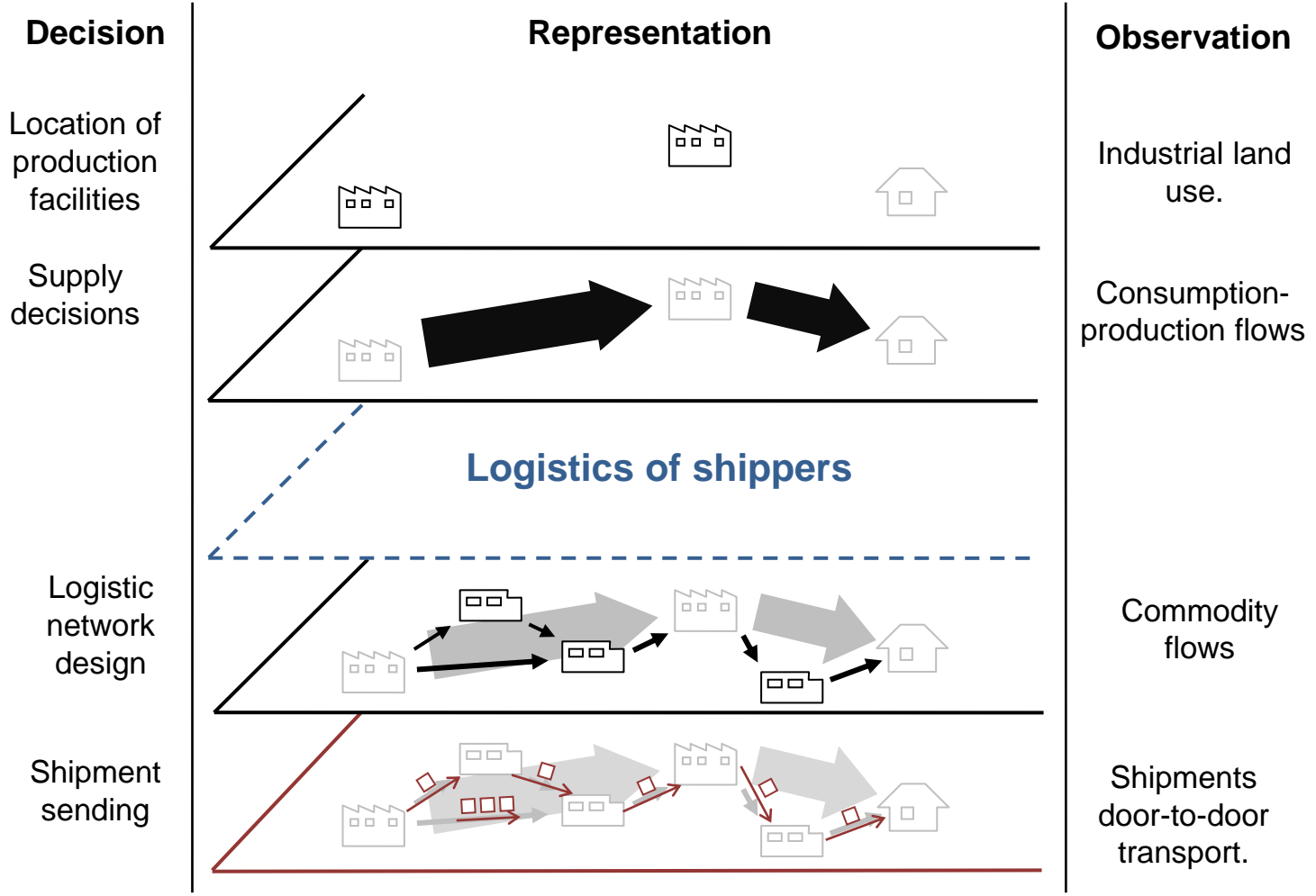
# Freight transport demand (2/2)

## Representation

- Introduction
- I Systems Analysis
- II Modelling Framework
- III Costs Representation
- IV Logistic Imperatives
- Conclusion

- Objectives
- Decision Unit
- Supply
- Demand
- Full Representation

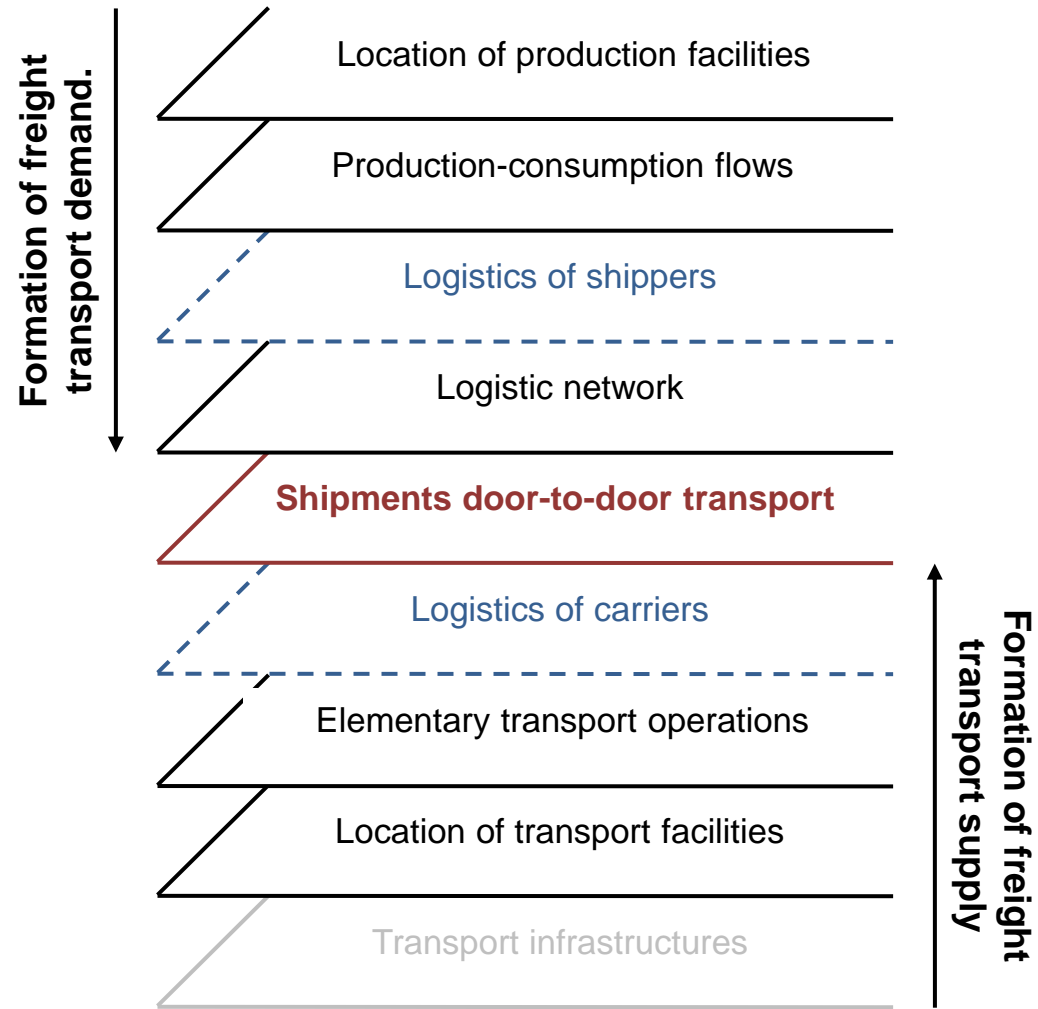


# Full representation

- Introduction
- I Systems Analysis
- II Modelling Framework
- III Costs Representation
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- Conclusion

- Objectives
- Decision Unit
- Supply
- Demand
- Full Representation



## Part II : A simple modelling framework

- Framework description
- Costs and trade-offs
- Extensions

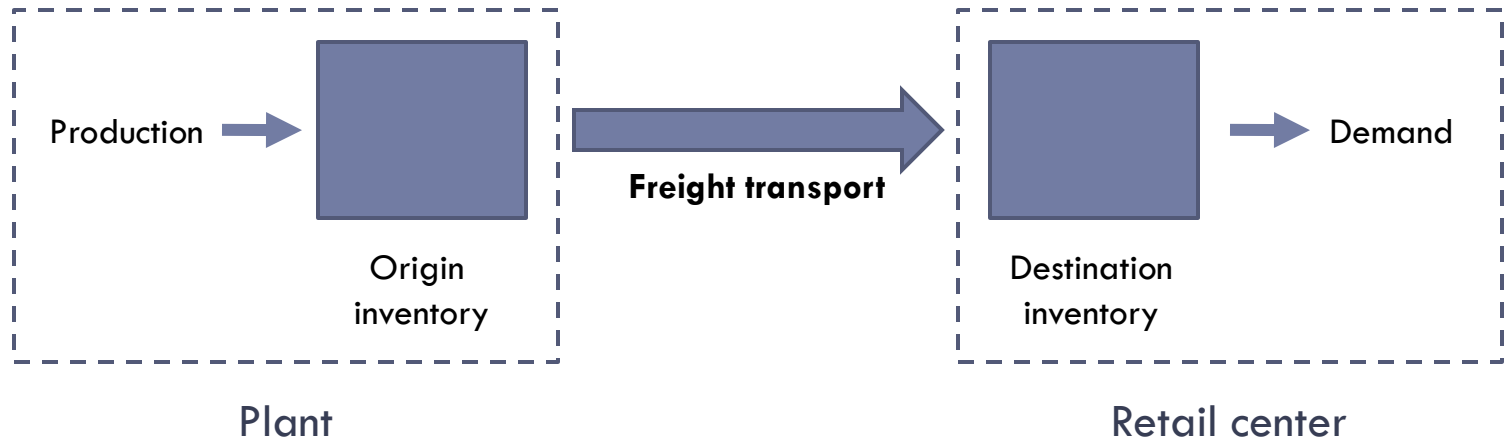
*Based on Chapters 3, 6 and 7*



# Framework description (1/3)

## Specification

### ■ A simple supply chain



Introduction  
I Systems Analysis  
II Modelling Framework  
III Costs Representation  
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Conclusion

Framework  
Costs and trade-offs  
Extensions

# Framework description (2/3)

## Characteristics

Introduction  
I Systems Analysis  
II Modelling Framework  
III Costs Representation  
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Conclusion

Framework  
Costs and trade-offs  
Extensions

- Many modelling options:
  - ▣ Demand: continuous/periodic, deterministic/stochastic, etc
  - ▣ Commodity: perishable or not
  - ▣ Customers: backlogging or not
  - ▣ Transport costs: linear or not
- Many features disregarded by construction:
  - ▣ More complicated spatial interactions (one-to-many, many-to-many)
  - ▣ Production/Marketing/Transport interactions
  - ▣ Intermediate inventories
  - ▣ Advanced logistic strategies (MTO-MTS, postponement, highly variable demand)
  - ▣ Market structure and contracts, information availability

# Framework description (3/3)

## Costs taken into account

- Transport costs
- Inventory costs
  - Pipeline
  - Cycle
  - Safety
- Customer costs

Introduction  
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Framework  
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Extensions

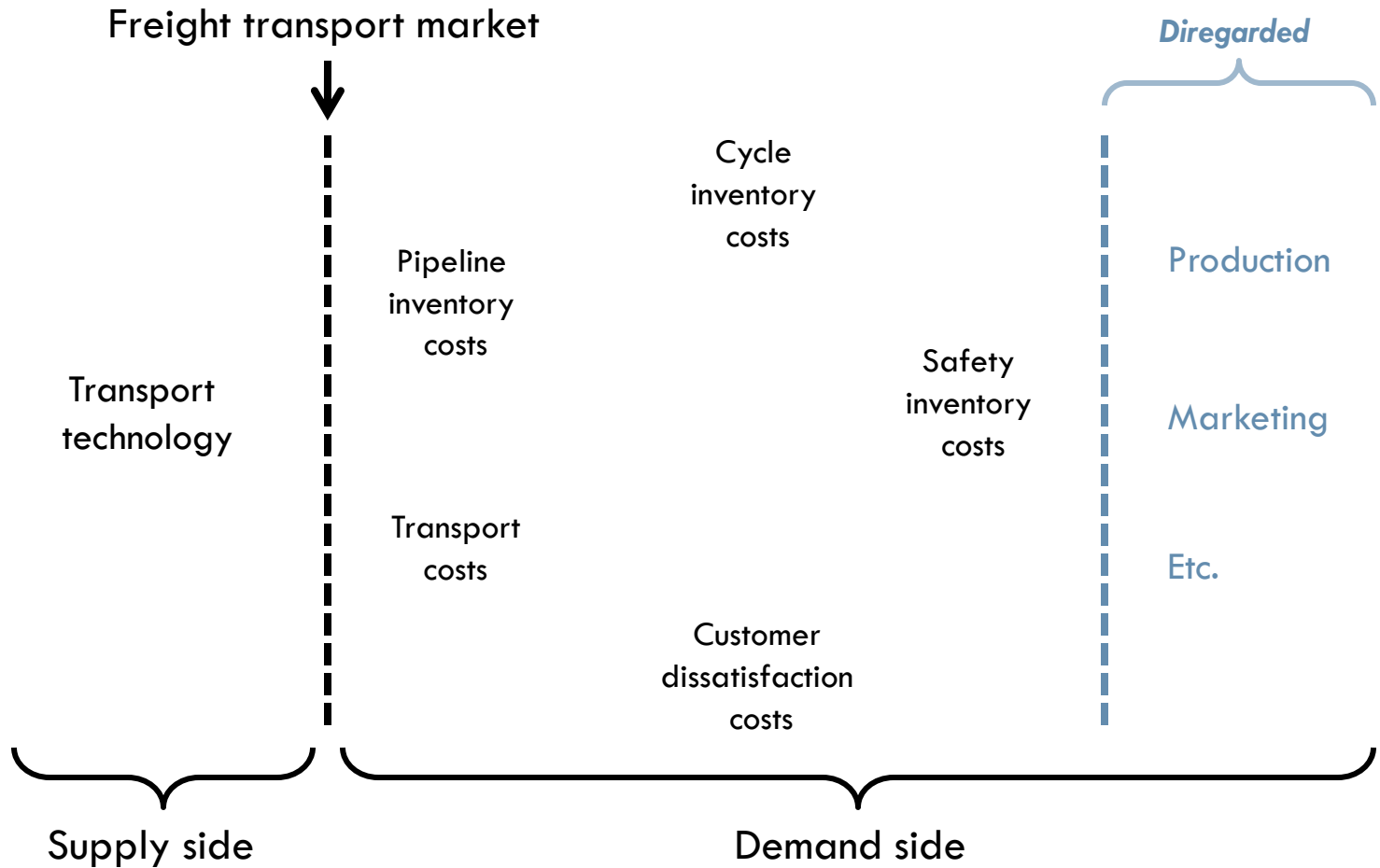
# Costs and trade-offs (1/3)

## Place in the freight transport system

- Introduction
- I Systems Analysis
- II Modelling Framework**
- III Costs Representation
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- Conclusion

- Framework
- Costs and trade-offs**
- Extensions



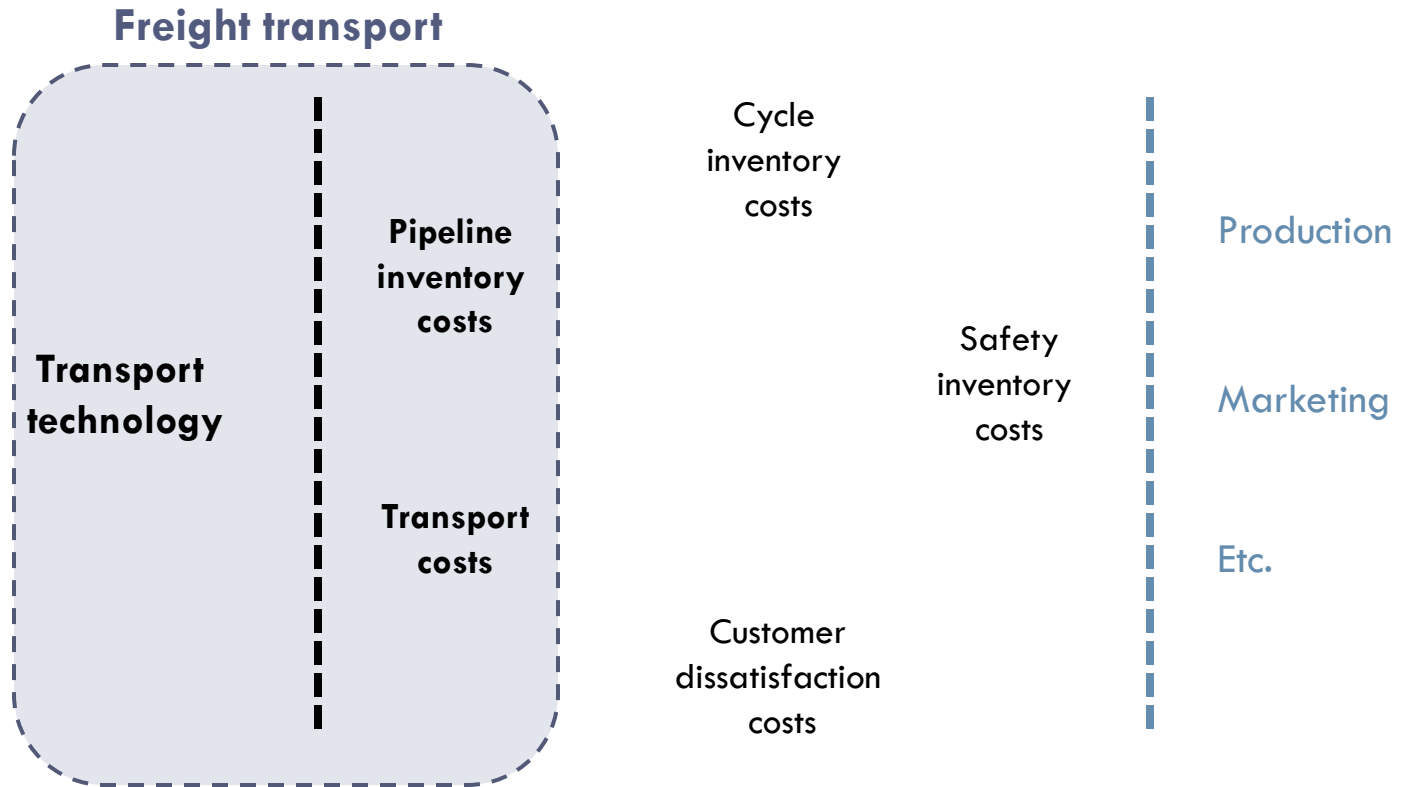
# Costs and trade-offs (2/3)

## The classic freight transport modelling approach

- Introduction
- I Systems Analysis
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- Conclusion

- Framework
- Costs and trade-offs**
- Extensions



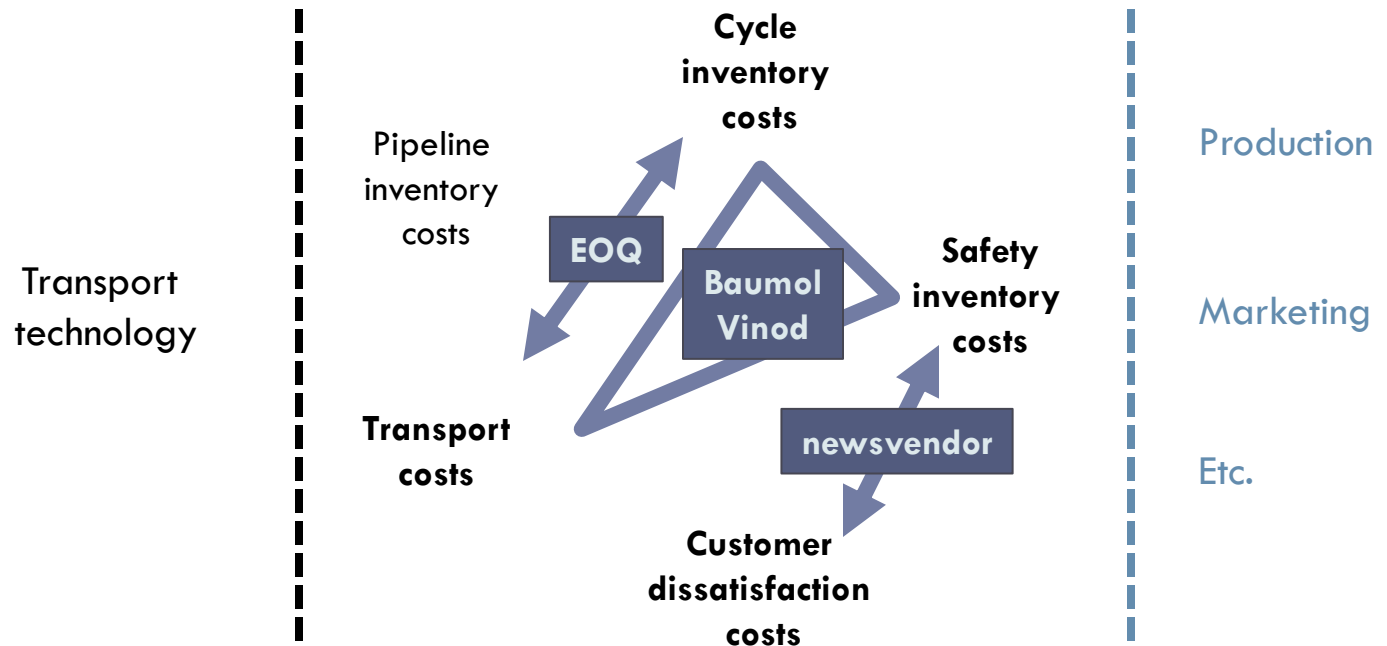
# Costs and trade-offs (3/3)

## Some logistics-based microeconomic models

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- Framework
- Costs and trade-offs**
- Extensions



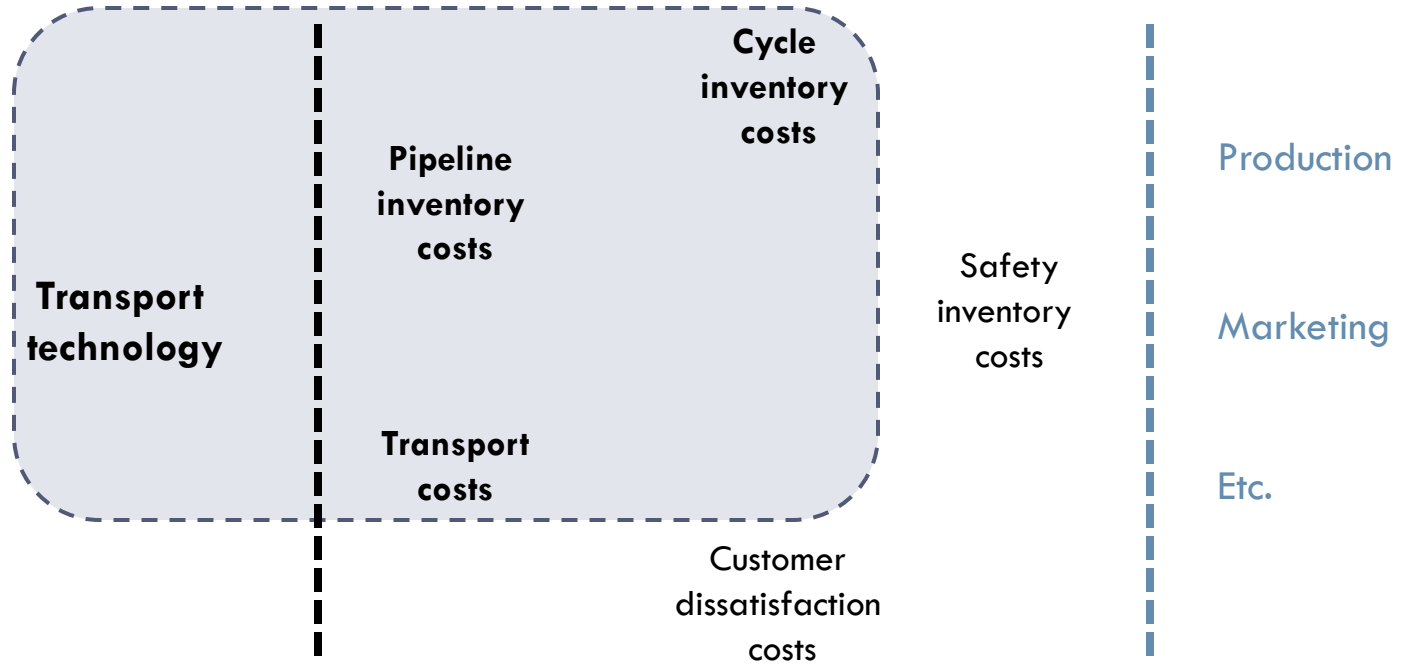
# Extensions (1/2)

## Improving the representation of costs

- Introduction
- I Systems Analysis
- II Modelling Framework**
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- Conclusion

- Framework
- Costs and trade-offs
- Extensions**



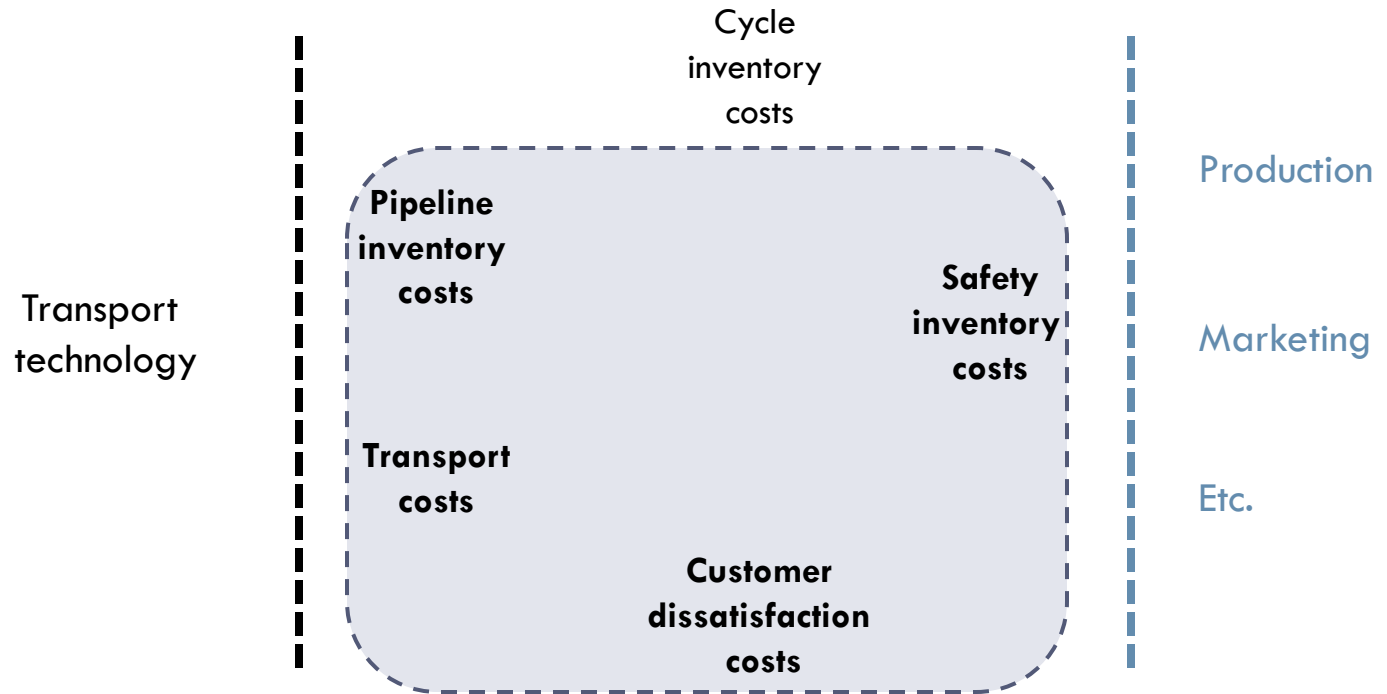
# Extensions (2/2)

## Logistic drivers of freight transport demand

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- Conclusion

- Framework
- Costs and trade-offs
- Extensions**





## Part III : Improving the representation of costs

- Objectives
- Qualitative observations
- Carriers
- Shippers
- Market equilibrium
- Some results
- Conclusion

*Based on Chapter 5 and 6*

# Objectives

Introduction  
I Systems Analysis  
II Modelling Framework  
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Objectives  
Observations  
Carriers  
Shippers  
Market Equilibrium  
Some Results  
Conclusion

- Model the freight transport market equilibrium with:
  - Explicit shipment sizes
  - Detailed description of the transport technology
  - Endogeneous demand with explicit logistic decisions
- Explain some observed qualitative properties of freight transport prices
- Make a first step towards a comprehensive model of prices simple and realistic enough to be included in a spatialised freight transport model

# Qualitative observations

Introduction  
I Systems Analysis  
II Modelling Framework  
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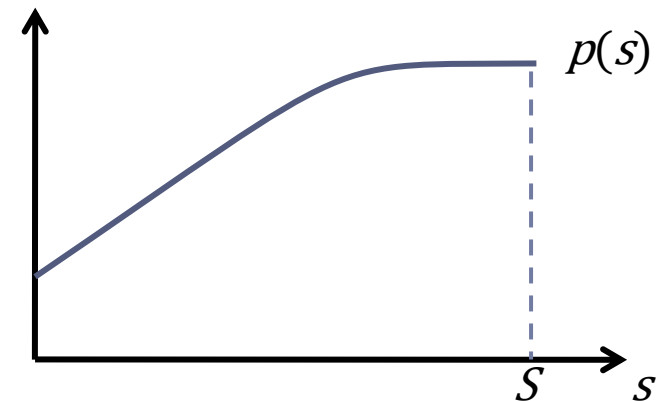
Objectives  
Observations  
Carriers  
Shippers  
Market Equilibrium  
Some Results  
Conclusion

- Market studied: industrial freight transport by trucks

- On a given OD pair, price schedule  $p(s)$

properties:

- $p(0) > 0$
- Unit rates decrease,
- Flat for large shipment sizes



- Objective: finding the minimal set of hypotheses accounting for these properties

# Carriers (1/5)

## Technology

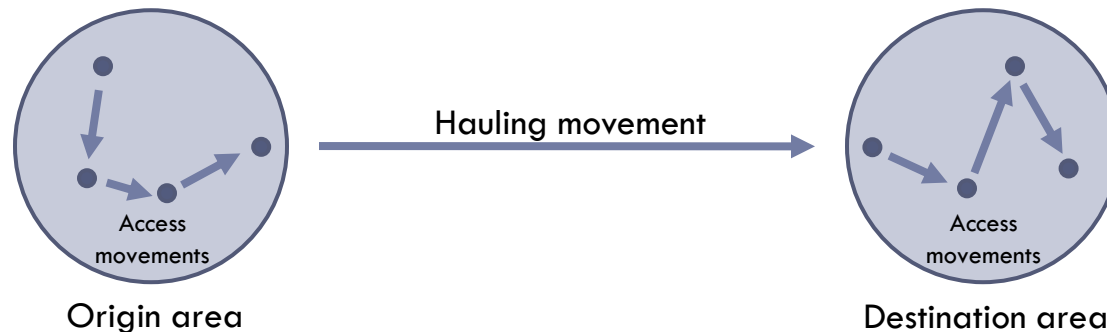
Introduction  
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Conclusion

Objectives  
Observations

Carriers

Shippers  
Market Equilibrium  
Some Results  
Conclusion

### ■ Spatial configuration



### ■ Technology:

- Each transport operation implies a shipment specific access cost  $b$  and a joint hauling cost  $c$
  - Vehicles of capacity  $S$
  - Fleets are fully flexible, no routing, no backhaul.
- Simplifying assumption: shipments can be of size 1, 2 or 3. Vehicle capacity is 3. (Objective: to avoid the bin-packing problem)

# Carriers (2/5)

## Market structure

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Conclusion

- Carriers are price-taker, profit maximising.
- Carriers can freely enter and leave the market.
- Denote  $Q_i$  the amount of shipments of size  $i$  a carrier will have to transport.
- For each carrier, the demands for transport of each shipment size are **stochastics**. They can decide its expected value  $q_i$

$$Q_i \approx U \left( \left(1 - \frac{K_s}{2}\right) q_i, \left(1 + \frac{K_s}{2}\right) q_i \right)$$

# Carriers (3/5)

## Cost function

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- Separability of the cost function:

$$C(Q_1, Q_2, Q_3) = C(Q_1, Q_2) + C(Q_3)$$

- Full truck load:

$$C(Q_3) = (b + c)Q_3$$

- Less than truck load: two cases

- ▣  $Q_1 \geq Q_2$ :  $Q_2$  full trucks +  $Q_1/3$  full trucks
- ▣  $Q_1 < Q_2$ :  $Q_1$  full trucks,  $Q_2 - Q_1$  partially empty trucks

$$C(Q_1, Q_2) = b(Q_1 + Q_2) + \frac{c}{3}\Delta + cQ_2$$

$$\Delta = (Q_1 - Q_2)^+$$

# Carriers (4/5)

## Marginal cost pricing

- Profit maximisation conditions:

$$\forall i, \quad \frac{\partial}{\partial q_i} \mathbb{E}[C] = p(i)$$

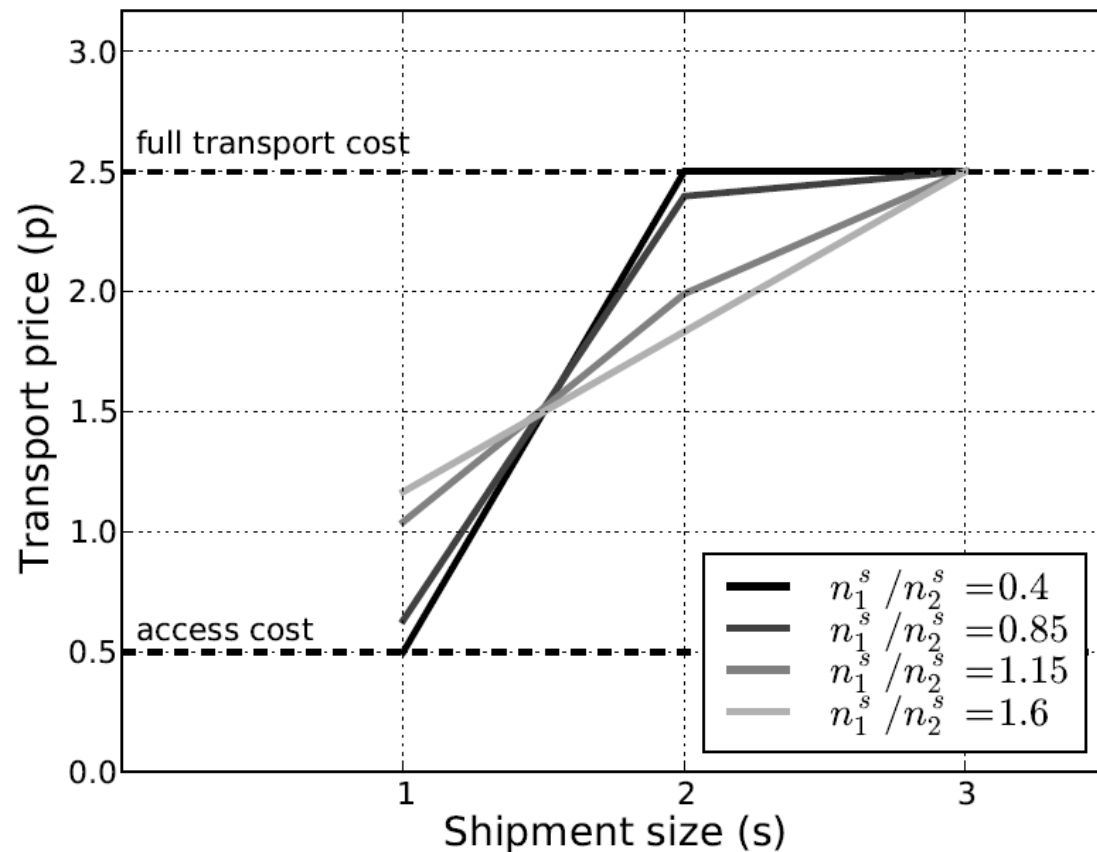
- For a given transport demand  $(n_1^s, n_2^s)$ :

$$\begin{cases} p(1) = b + c \frac{\partial \delta}{\partial q_1} (n_1^s, n_2^s) \\ p(2) = b + c + c \frac{\partial \delta}{\partial q_2} (n_1^s, n_2^s) \\ p(3) = b + c \end{cases}$$

# Carriers (5/5)

## Price schedules

### ■ Price schedules for given demands



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# Shippers

## Description

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Shippers  
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Conclusion

- Shippers are described by:
  - ▣ The exogenous commodity flow rate  $Q$
  - ▣ The exogenous commodity value of waiting time savings  $a$  (distributed in the population)
- Shipment sizes are endogeneous. Their choice is EOQ-like
- As a result, transport operations of shipments of distinct sizes are substitutes

# Market Equilibrium

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Shippers  
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- The sequence of decisions:
  1. Carriers display their prices
  2. Each shipper chooses a carrier
  3. Given this carrier's price schedule, each shipper chooses the size of its shipments
- The market equilibrium exists and is unique

# Some results

## Cost structure and market structure

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Conclusion

- The costs of carriers are characterised by:
  - ▣ Constant returns to scale
  - ▣ Increasing returns to scope
- The costs of shippers are endowed with increasing returns to scale. This is due to the presence of user inputs
- Price variability is not necessarily evidence of market distortion
- No simple relationship between model parameters and the average loading factor
- Information availability: a rationale for contracts heterogeneity

# Part IV : Logistic imperatives and mode choice

*Based on Chapter 7*

# One mode (1/2)

## Framework

Introduction  
I Systems Analysis  
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One Mode  
Two Modes

- Consider a simple supply chain
  - ▣ Periodic review
  - ▣ Linear transport costs
  - ▣ Stochastic demand
  - ▣ Customers wait (backlogging hypothesis)
- There is an optimal logistic policy
  - ▣ Aim: keeping the destination inventory level around a target: the **safety stock**
  - ▣ Outcome of a trade off between inventory costs and customer dissatisfaction costs

# One mode (2/2)

## Microeconomic properties

- It is possible to calculate the derivative of the full cost function with respect to the duration of the transport operation. This gives the **value of time** of the shipper.

$$\alpha = a_c + \frac{\zeta}{2\sqrt{1+\zeta}} \frac{\sigma}{d}$$

- Pipeline inventory cost
- Value of **supply chain reactivity** (proportional to the relative variance of the demand)
- This framework can be extended to:
  - Stochastic travel time (and yields a value of reliability)
  - Two modes

# Two modes

## Basic presentation

- Combining two modes optimally is possible but not easy: a naive heuristic is used
- Microeconomic mechanism: increasing the heavy mode share implies:
  - A lower transport cost
  - A lower supply chain reactivity
    - Higher inventory costs
    - Higher customer dissatisfaction
- Used together, distinct modes have asymmetric roles

# Conclusion



# Assessment

- Making the shipment size explicit in freight transport models needs:
  - An improved systems analysis
  - Some empiric validation of the existing microeconomic theory
  - A detailed representation of technology and costs
- Outcomes:
  - A better knowledge of the cost structure of carriers
  - The strong difference between the costs of carriers and of shippers
  - A first step towards the microeconomic modelling of supply chains (with a logistics-based value of time)

# The big issue: introducing shipment size into fully-fledged spatialised simulation models

## Issues

- The supply side
  - Many constraints have been left aside
    - Spatial constraints: empty return, more complex routing
    - Temporal constraints: wait or leave?
  - Consolidation cannot be represented
- The demand side
  - More complex logistics
    - Intermediate inventories
    - MTS/MTO...
  - Distinct products

# The big issue: introducing shipment size into fully-fledged spatialised simulation models

## Perspectives

- Introduction
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- II Modelling Framework
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- IV Logistic Imperatives
- Conclusion

- Mode choice should be easy (it is strongly compatible with EOQ-like models)
- A statistic approach may prove efficient for prices (but what about the linkage between shipment movements and vehicle movements?)
- A statistic approach (EUNET2.0-like) can be used for logistic networks (once shippers logistics is distinguished from carriers logistics)
- Data collection protocols should be adapted