The Impact of Dual Sourcing on Quantitative Microbiological Risk Assessment in Food Supply Chain Networks: the case of Egyptian strawberries

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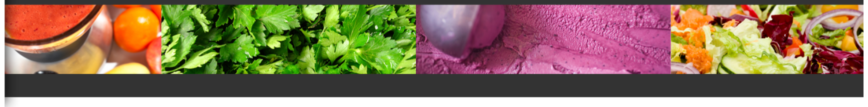
Introduction

- This work investigates the **impact of dual sourcing strategies** on **quality** of **fresh fruit** traded in international **food supply chains.**

- Dual sourcing is an established practice in supply chain management – see (Veeraraghavan and Scheller-Wolf, 2008; Schimpel, 2010; Klosterhalfen et al., 2011).



Dual sourcing

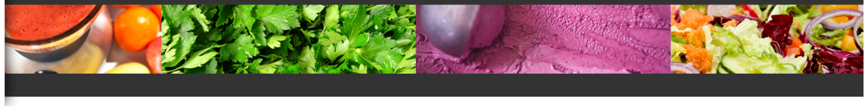
- When a company adopts **dual sourcing,** it typically ships a **large volume** of products via a **cheap,** but usually **slow shipping mode,** which we will call “regular”.
- However, the company also has the flexibility to **ship more products** when needed via an **expedited shipping mode,** which is more **expensive.**
- Companies adopt dual sourcing to **enhance flexibility** of their **sourcing strategy.**

Dual sourcing

- An issue that, to the best of our knowledge, has not been investigated yet in the literature, is the **impact of dual sourcing on fresh produce quality**.

- Most of existing literature on dual sourcing focuses on products such as **electronic components, spare parts management, car manufacturing**, etc (Schimpel, 2010).

- Clearly, a **longer transportation time** does **not affect** the **quality** of these products.

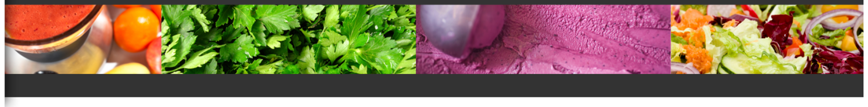


Dual sourcing

- However, **little research exists** on **dual sourcing applied to fresh food produce.**

- For fresh produce, a **lean and fast chain** is key to product quality on retail shelves.

- An interesting issue then is to study **if dual sourcing**, which is a common strategy among firms to reduce costs, **may jeopardize product quality** in food supply chains.



Research questions

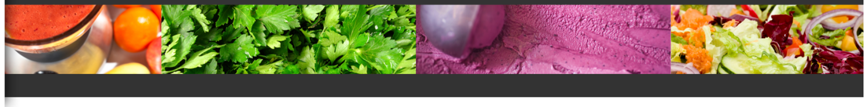
1. Does a dual sourcing inventory control policy, whilst reducing costs, **guarantee a sufficient quality** at consumption and reasonable waste?

2. How **sensitive** is a dual sourcing policy to **variations of initial quality and temperatures** along the chain?

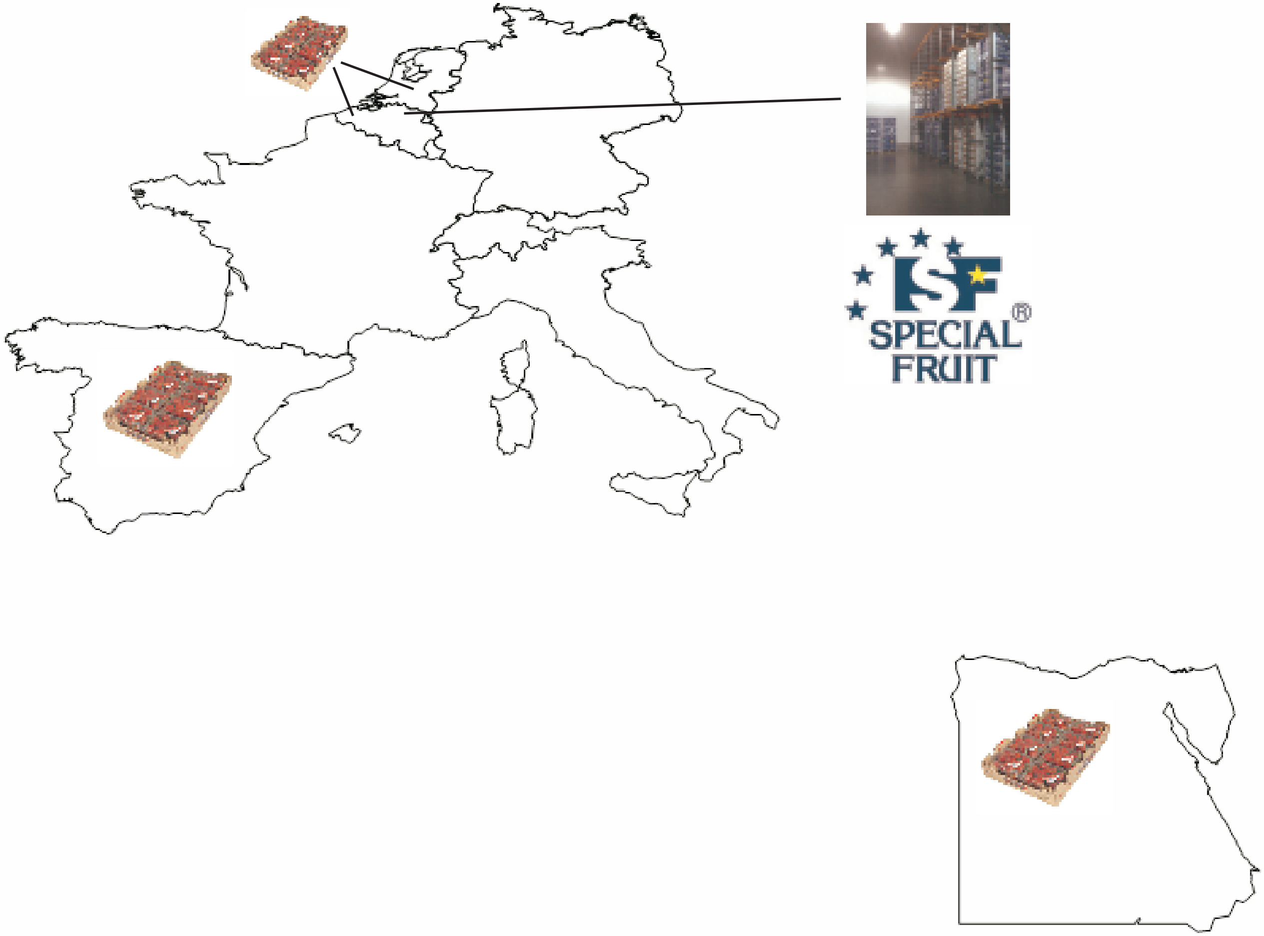
3. What is the **impact of fuel cost** variation on final product **quality** and on **waste**?

Case: fresh strawberries

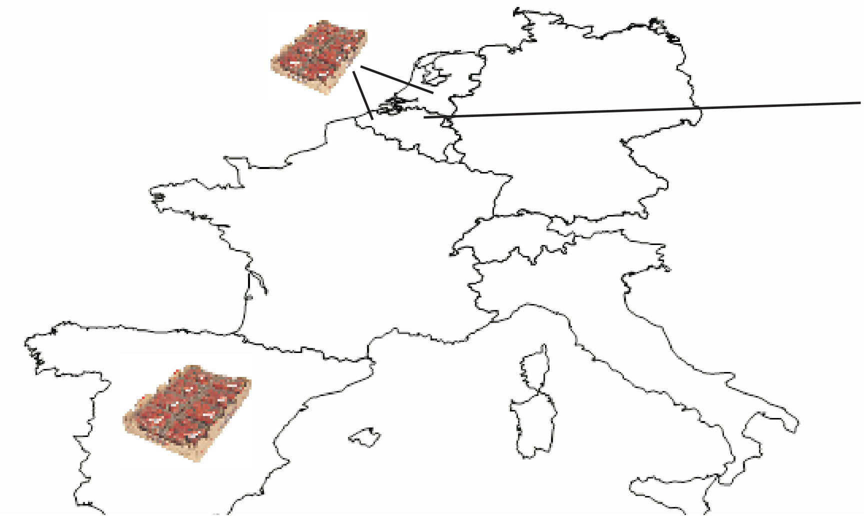
- Industrial partner
  - Special Fruit, Meer, Belgium
- Import areas
  - Egypt
  - Spain
  - Netherlands
- Quality
  - growth of Botrytis cinerea
- Safety
  - *no safety threats*

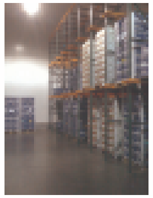



Strawberry supply chain sourcing areas and distribution center



Strawberry supply chain sourcing areas and distribution center

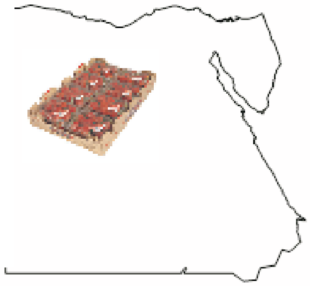




SPECIAL FRUIT

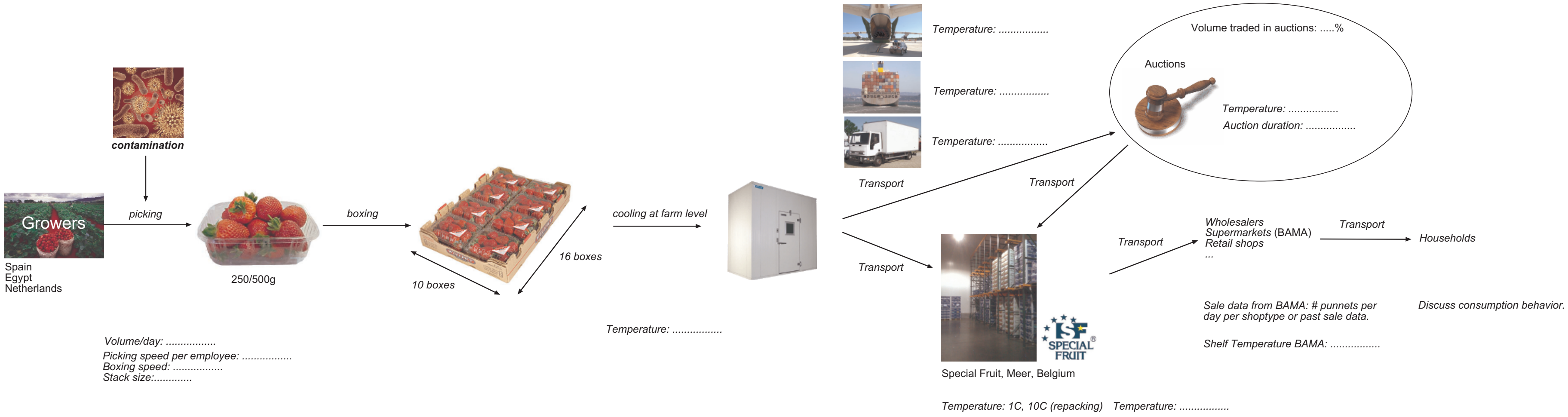
Table 1: Import regions of strawberries for different seasons

Product	Availablilty												Country
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Strawberry			■	■	■	■	■	■	■	■	■	■	Belgium
	■	■									■	■	Egypt
			■	■	■	■	■	■	■	■	■	■	Netherlands
	■	■	■	■	■							■	Spain



Strawberry supply chain sourcing areas and distribution center

General Chain (Strawberries)



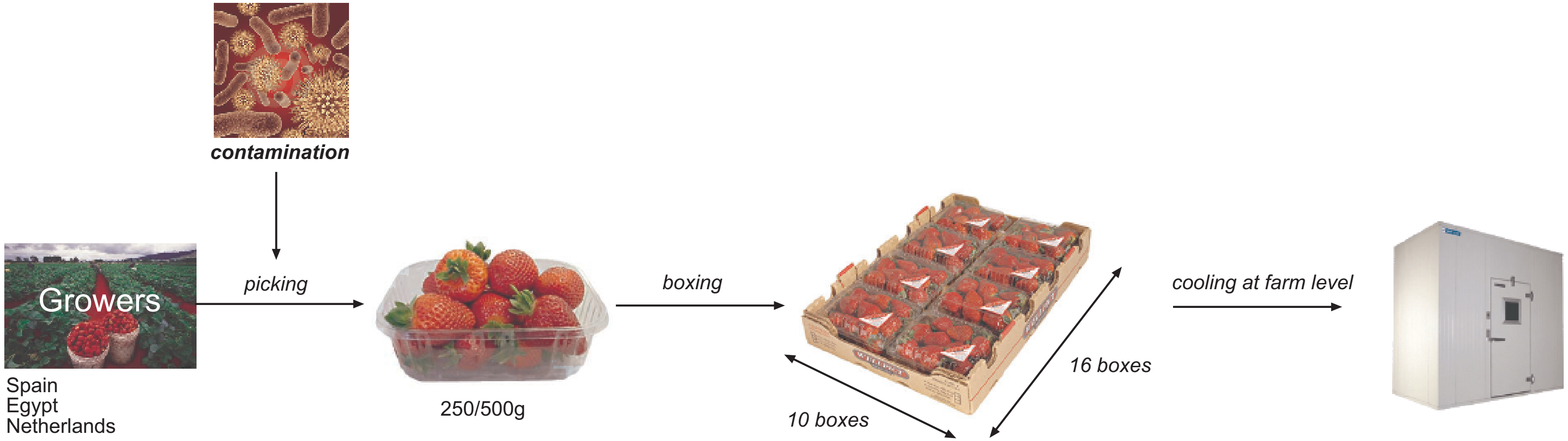
Volume/day: ....

Picking speed per employee: ....

Boxing speed: ....

Stack size:............

General Chain (Strawberries)



contamination

Growers

picking

boxing

cooling at farm level

Spain
Egypt
Netherlands

250/500g

10 boxes

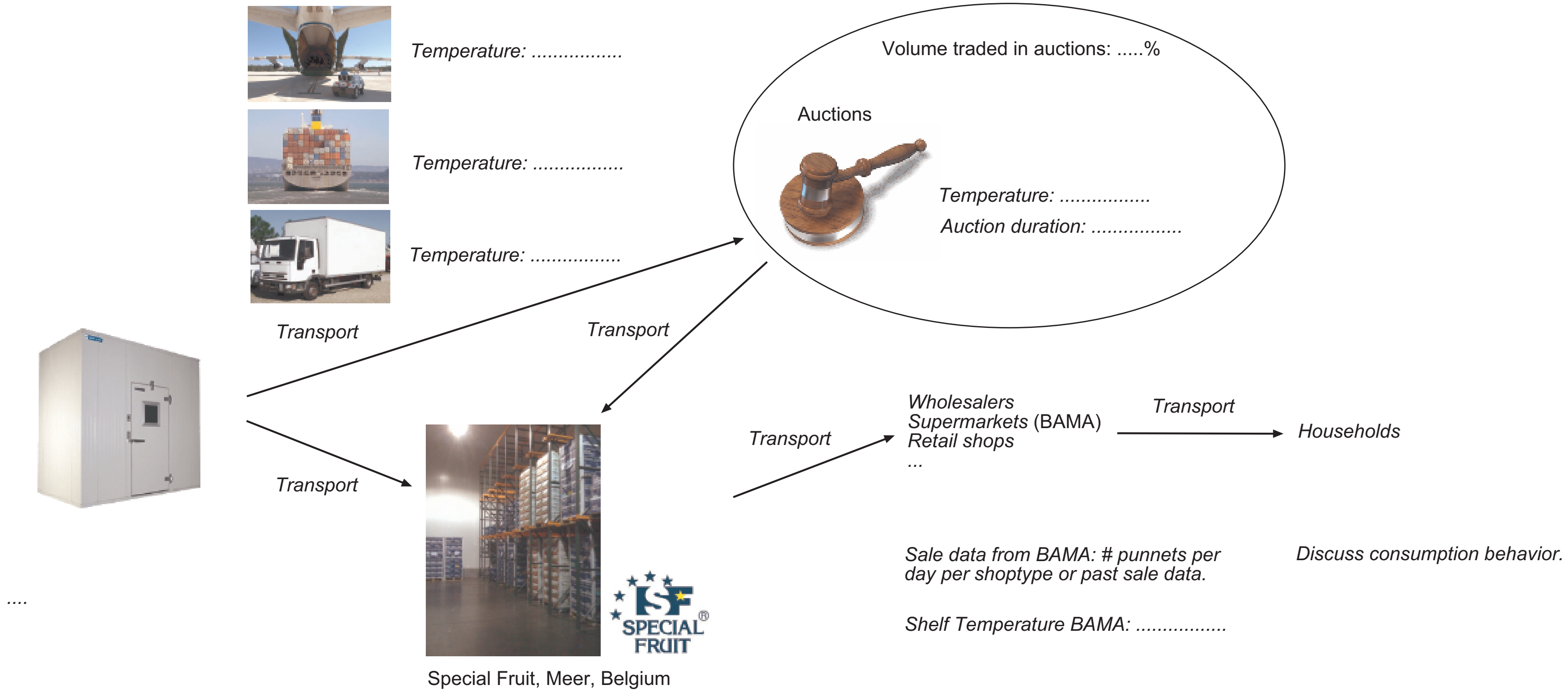
16 boxes

Temperature: ....

Volume/day: ....

Picking speed per employee: ....
Boxing speed: ....
Stack size:.............

General Chain (Strawberries)



Temperature: ....

Temperature: ....

Temperature: ....

Transport

Transport

Volume traded in auctions: .....%

Auctions

Temperature: ....

Auction duration: ....

Transport

Transport

Wholesalers
Supermarkets (BAMA)
Retail shops
...

Transport

Households

....

Special Fruit, Meer, Belgium

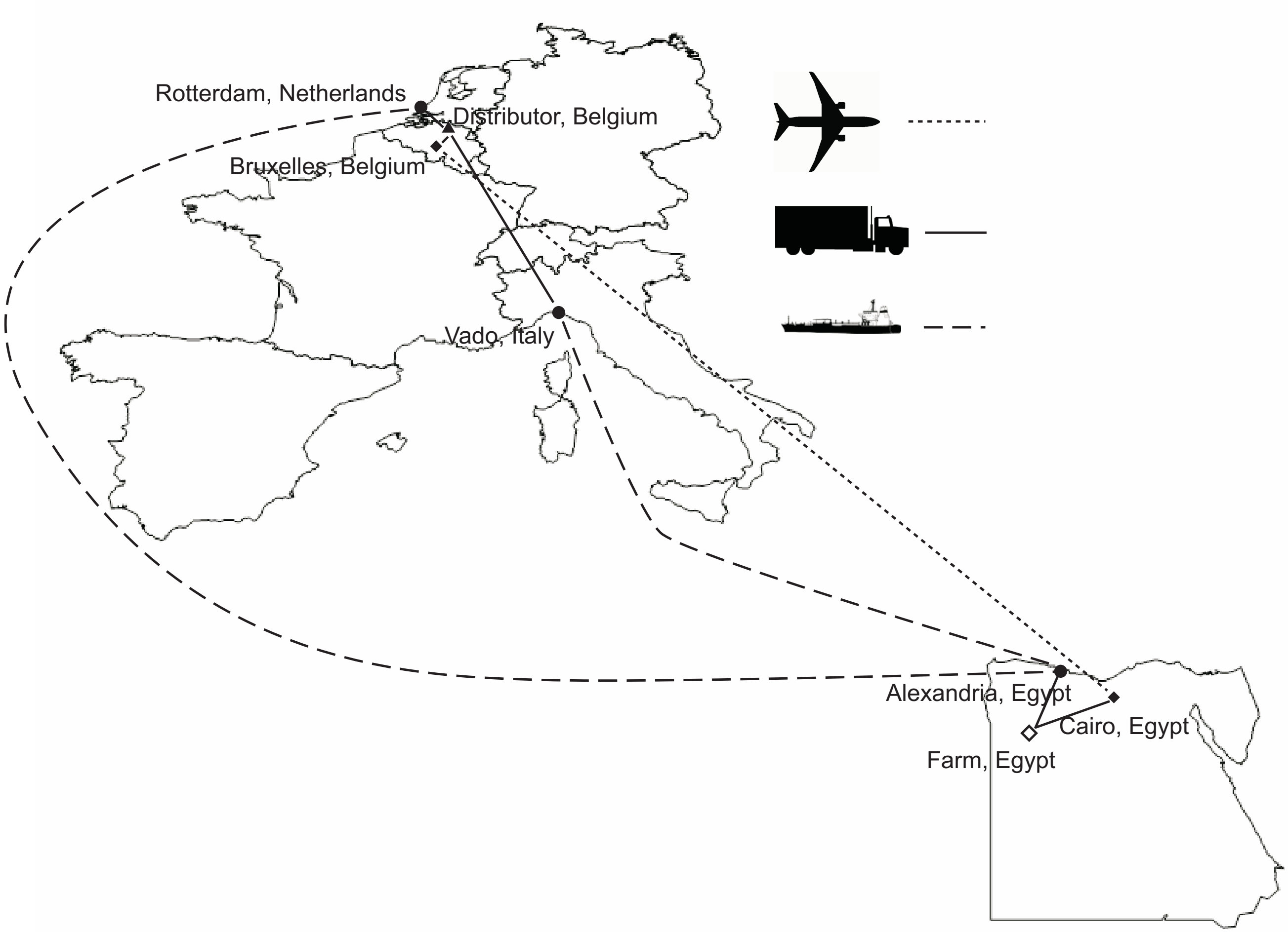
Sale data from BAMA: # punnets per day per shoptype or past sale data.

Shelf Temperature BAMA: ....

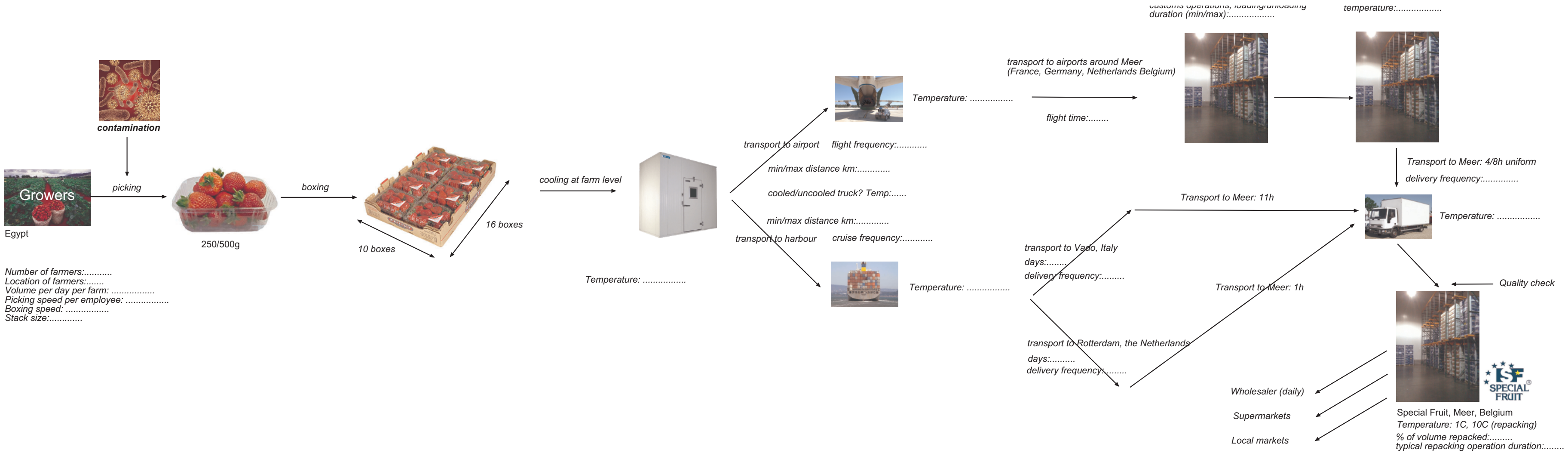
Discuss consumption behavior.

Temperature: 1C, 10C (repacking)   *Temperature: ....*

Egypt - Netherlands Supply Chain (Strawberries)



Egypt - Netherlands Supply Chain (Strawberries)



contamination

Growers

Egypt

picking

250/500g

boxing

10 boxes

16 boxes

cooling at farm level

Temperature: ....

Number of farmers:...........
Location of farmers:.......
Volume per day per farm: ....
Picking speed per employee: ....
Boxing speed: ....
Stack size:............

transport to airport
flight frequency:...........
min/max distance km:............
cooled/uncooled truck? Temp:......
min/max distance km:............
transport to harbour
cruise frequency:...........

Temperature: ....

flight time:........

transport to airports around Meer
(France, Germany, Netherlands Belgium)

customs operations, loading/unloading
duration (min/max):.................

temperature:.................

Transport to Meer: 4/8h uniform
delivery frequency:.............

Transport to Meer: 11h

Temperature: ....

transport to Vado, Italy
days:........
delivery frequency:.........

Transport to Meer: 1h

Quality check

transport to Rotterdam, the Netherlands
days:..........
delivery frequency:........

Wholesaler (daily)

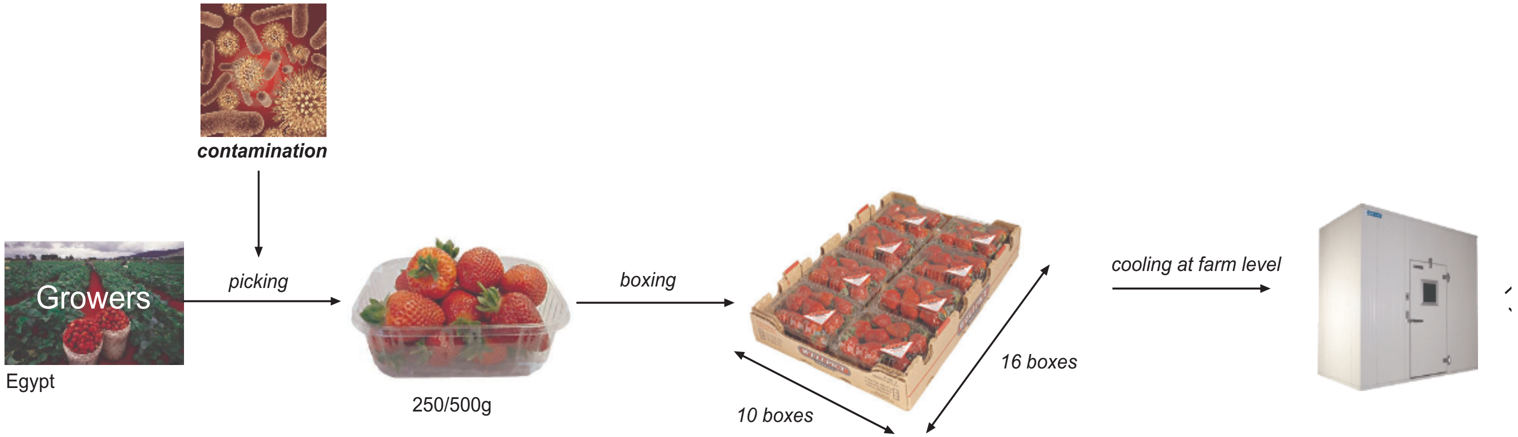
Supermarkets

Local markets

Special Fruit, Meer, Belgium
Temperature: 1C, 10C (repacking)
% of volume repacked:.........
typical repacking operation duration:........

Please provide a (representative) list of customers and shipping locations
Please provide (representative) daily volumes per customer
Please provide (representative) delivery frequencies per customer

Egypt - Netherlands Supply Chain (Strawberries)



contamination

Growers

Egypt

picking

250/500g

boxing

10 boxes

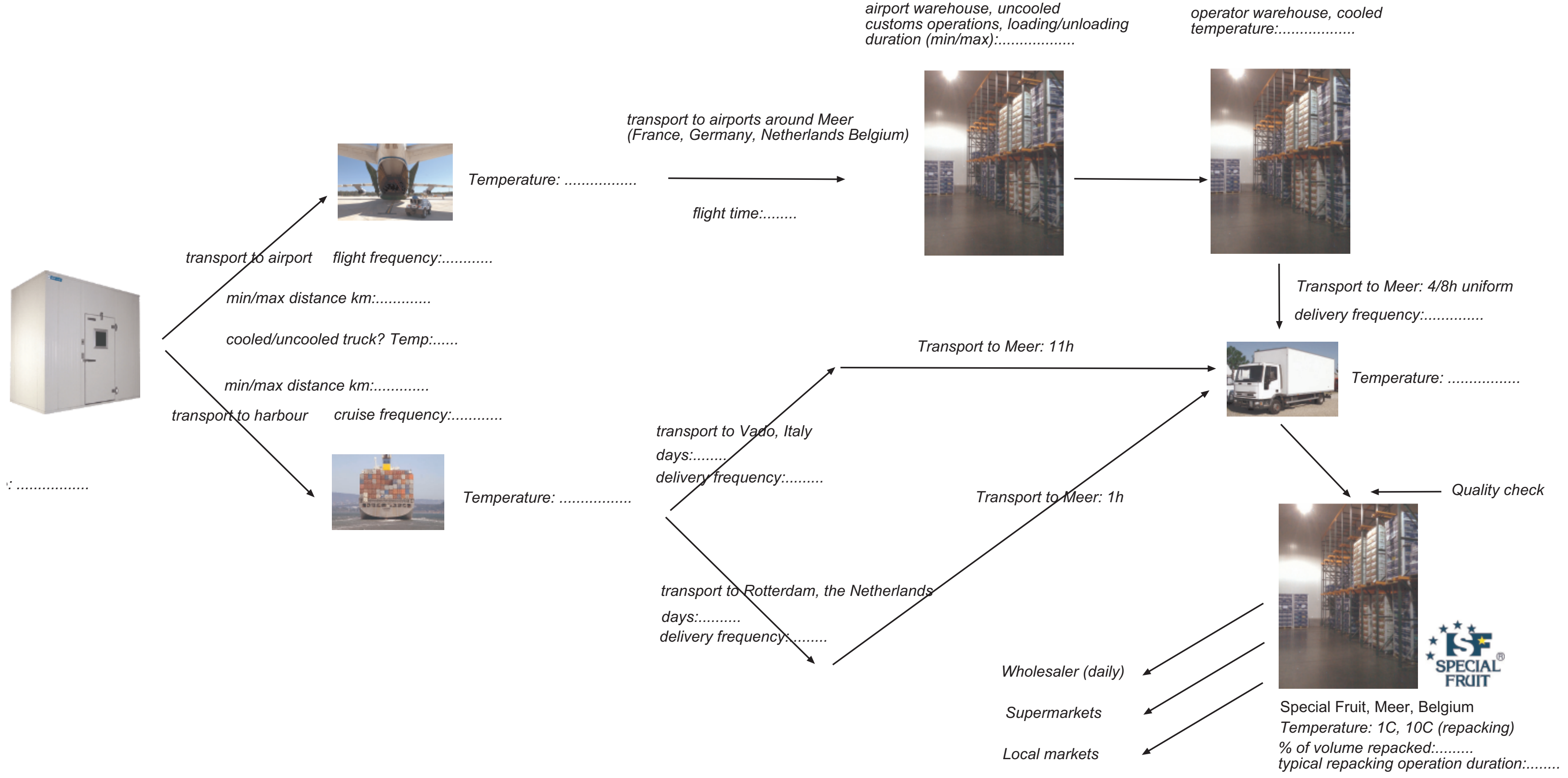
16 boxes

cooling at farm level

Number of farmers:...........
Location of farmers:.......
Volume per day per farm: ....
Picking speed per employee: ....
Boxing speed: ....
Stack size:.............

Temperature: ....

Egypt - Netherlands Supply Chain (Strawberries)



: ....

transport to airport

flight frequency:............

min/max distance km:.............

cooled/uncooled truck? Temp:......

min/max distance km:.............

transport to harbour

cruise frequency:............

Temperature: ....

transport to airports around Meer
(France, Germany, Netherlands Belgium)

flight time:........

airport warehouse, uncooled
customs operations, loading/unloading
duration (min/max):..................

operator warehouse, cooled
temperature:..................

Transport to Meer: 4/8h uniform

delivery frequency:..............

Temperature: ....

transport to Vado, Italy

days:........

delivery frequency:.........

Transport to Meer: 11h

transport to Rotterdam, the Netherlands

days:..........

delivery frequency:........

Transport to Meer: 1h

Temperature: ....

Quality check

Special Fruit, Meer, Belgium
Temperature: 1C, 10C (repacking)
% of volume repacked:.........
typical repacking operation duration:........

Wholesaler (daily)

Supermarkets

Local markets

Please provide a (representative) list of customers and shipping locations
Please provide (representative) daily volumes per customer
Please provide (representative) delivery frequencies per customer

Costs

- Transportation costs per ton of products
  - Boat
  - Plane
  - Truck

- Holding costs at producer, DC, retailers

- Boat is typically cheaper than plane but it is slower!

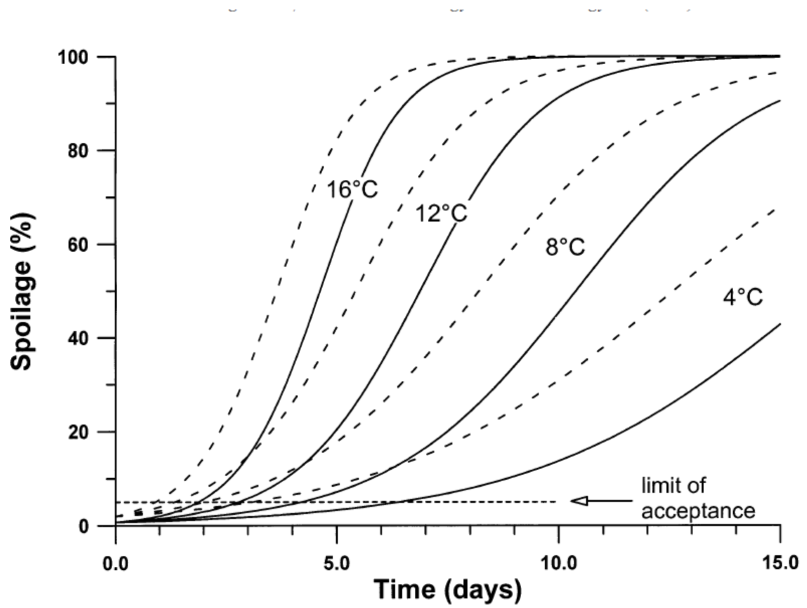
Problem parameters

- Costs (see previous slide)
- Transportation time (lead-time)
  - Boat
  - Plane
  - Truck
- Service level (non-stockout probability)
  - Retailers
  - Producer
- Backordering cost
  - Distributor

Quality (Strawberries)

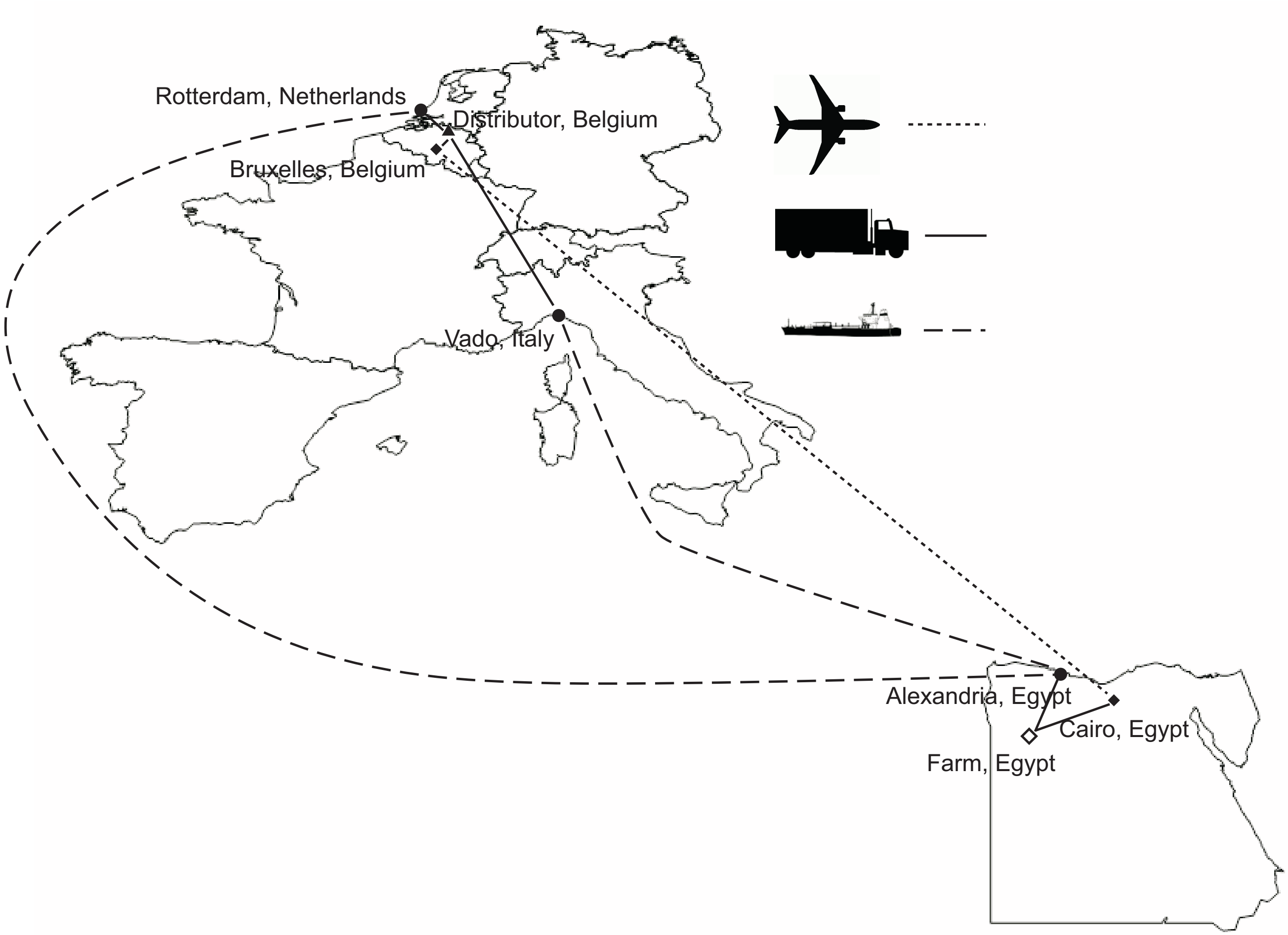
- Botrytis cinerea in strawberries (Hertog et al 1999)

Qt0=0.1

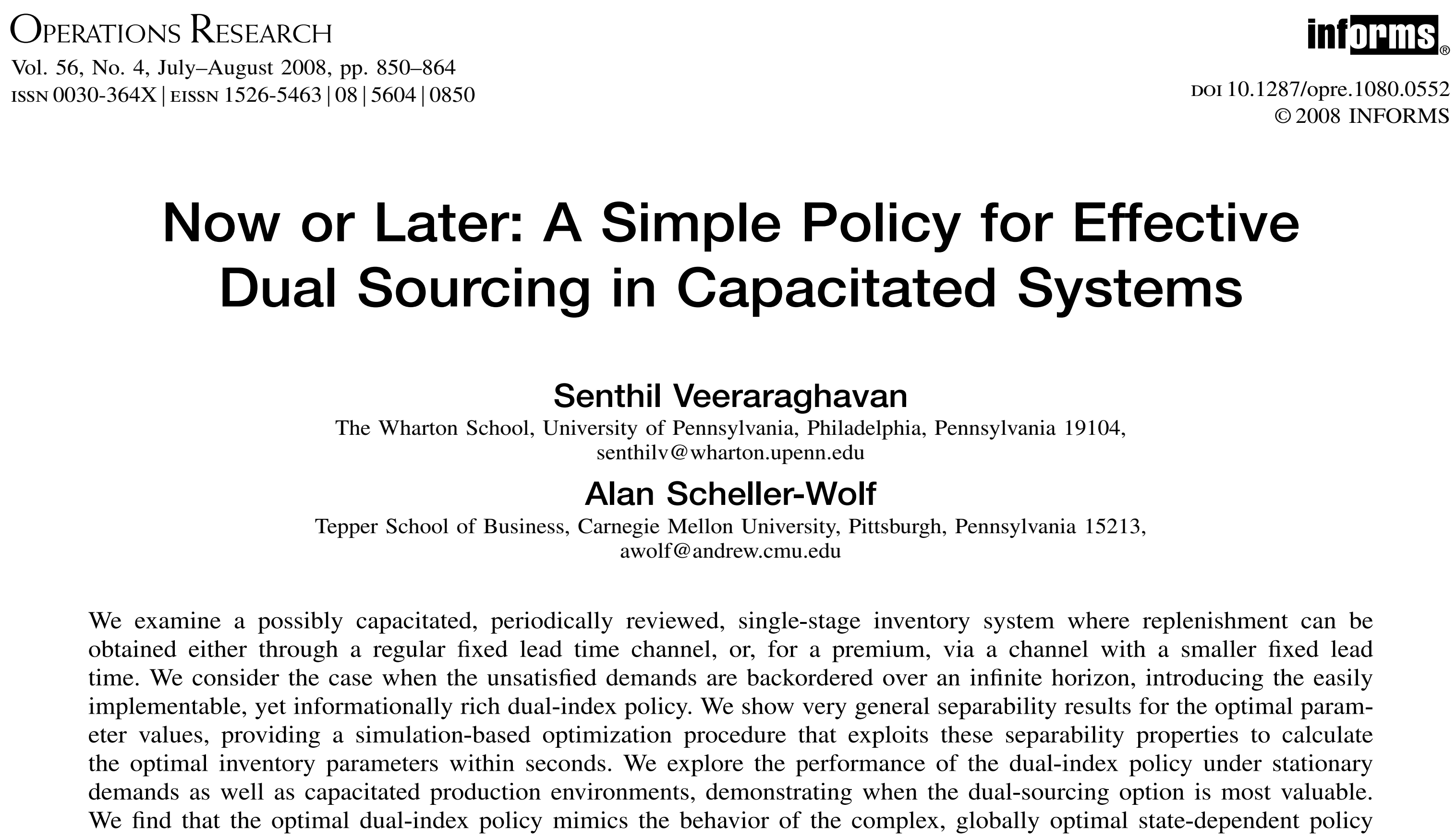


- Model includes the effect of temperature (k_s) and storage atmosphere (Rel_{MR}).

Egypt - Netherlands Supply Chain (Strawberries)



The dual-index policy



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Now or Later: A Simple Policy for Effective Dual Sourcing in Capacitated Systems

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We examine a possibly capacitated, periodically reviewed, single-stage inventory system where replenishment can be obtained either through a regular fixed lead time channel, or, for a premium, via a channel with a smaller fixed lead time. We consider the case when the unsatisfied demands are backordered over an infinite horizon, introducing the easily implementable, yet informationally rich dual-index policy. We show very general separability results for the optimal parameter values, providing a simulation-based optimization procedure that exploits these separability properties to calculate the optimal inventory parameters within seconds. We explore the performance of the dual-index policy under stationary demands as well as capacitated production environments, demonstrating when the dual-sourcing option is most valuable. We find that the optimal dual-index policy mimics the behavior of the complex, globally optimal state-dependent policy

The constant-order policy

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A comparison of the constant-order and dual-index policy for dual sourcing

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We analyze a single-product, periodic-review, stochastic demand inventory model with backorders and two supply options, a regular and a more expensive expedited one, with deterministic, offsetting lead times. Since the optimal policy for such a problem is generally unknown, several simpler policies have been proposed in the literature, e.g., the single-index (SIP), dual-index (DIP), or constant-order policy (COP). In previous research the DIP has been found to perform closely to the optimal policy in specific

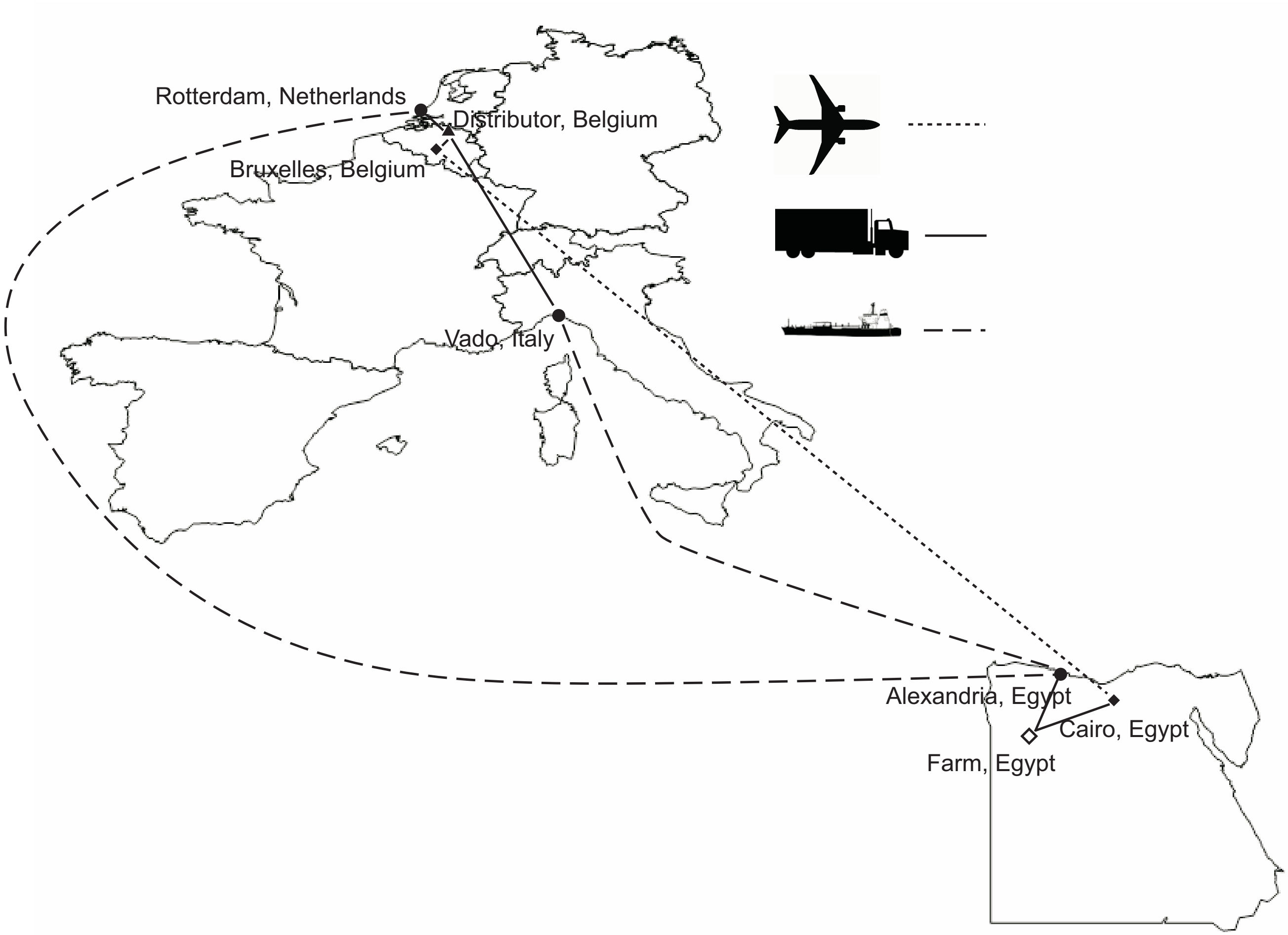
Genetic Algorithms for Policy Parameter Computation

- JGAP (Java Genetic Algorithm Package)

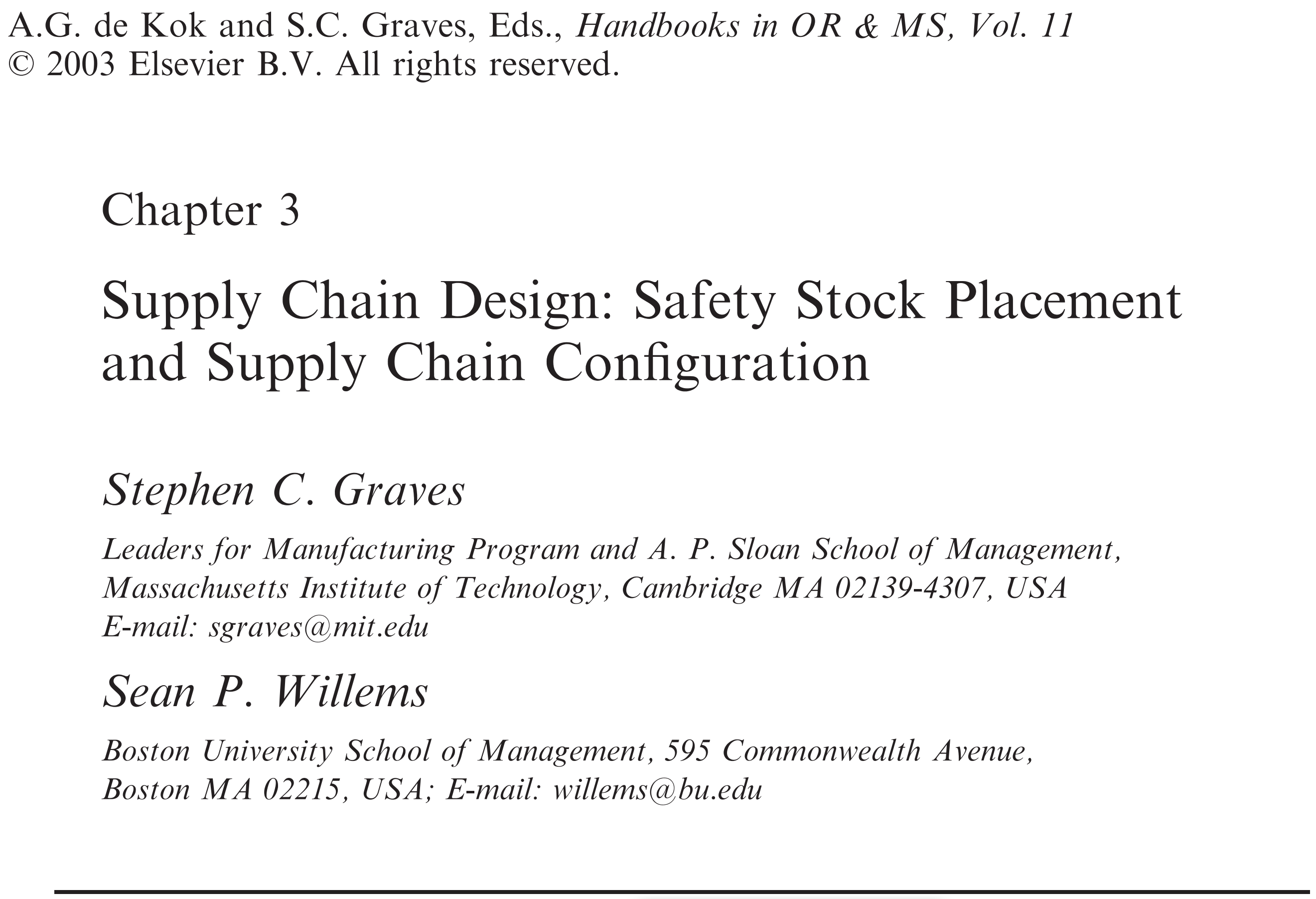
- A policy can be encoded as a chromosome:
  - COP -> [Q,Sm,St,Sw,St,Sf]
  - DIP -> [Se,Sm,St,Sw,St,Sf]

- JGAP automatically computes "good" policy parameters by mutation and recombination.

Egypt - Netherlands Supply Chain (Strawberries)



Stock positioning along supply chains



A.G. de Kok and S.C. Graves, Eds., *Handbooks in OR & MS, Vol. 11*

Chapter 3

Supply Chain Design: Safety Stock Placement and Supply Chain Configuration

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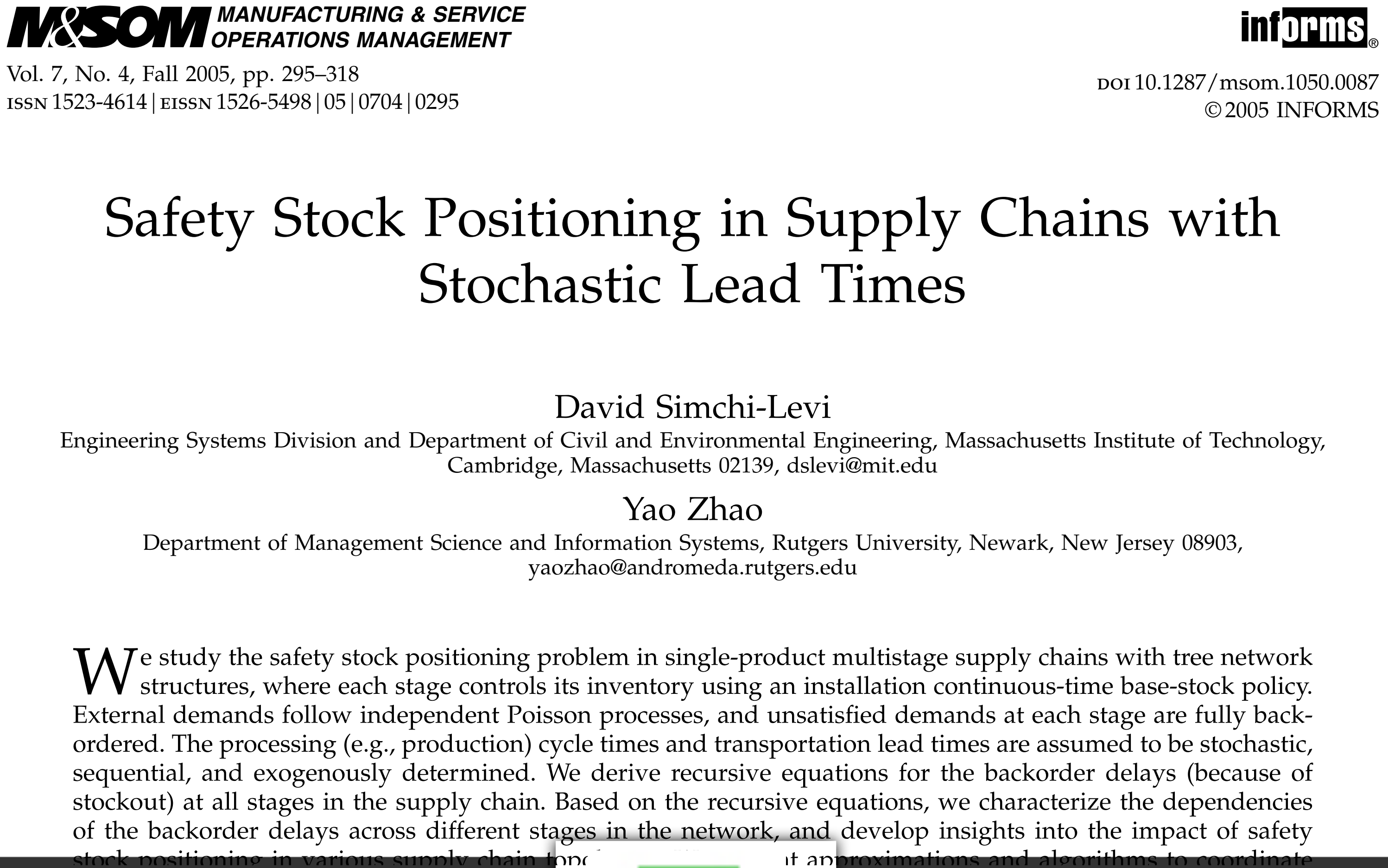
Stock positioning along supply chains



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Safety Stock Positioning in Supply Chains with Stochastic Lead Times

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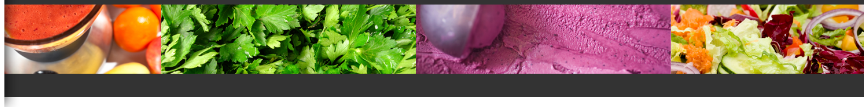
We study the safety stock positioning problem in single-product multistage supply chains with tree network structures, where each stage controls its inventory using an installation continuous-time base-stock policy. External demands follow independent Poisson processes, and unsatisfied demands at each stage are fully backordered. The processing (e.g., production) cycle times and transportation lead times are assumed to be stochastic, sequential, and exogenously determined. We derive recursive equations for the backorder delays (because of stockout) at all stages in the supply chain. Based on the recursive equations, we characterize the dependencies of the backorder delays across different stages in the network, and develop insights into the impact of safety stock positioning in various supply chain topo

Open issues

- Previous works deal with stock positioning w.r.t. **costs and service levels**
- There is no work that deals with **the impact of stock positioning on product quality**

Scenarios

- **Scenario 1 (base case COP):** This scenario constitutes the base case of our simulation analysis under a constant-order policy. The holding cost is set to 10 cents per punnet per day, the backordering cost is 50 cents per punnet per day, the cost of shipping 1 punnet by boat is 10 cents, the cost for shipping 1 punnet by plane is 30 cents. The solution obtained with GA sets the constant order quantity to *Q=24410*, and the order-up-to-levels for the expedite orders placed from Monday to Friday to *Se=[4065, 36471, 24434, 36626, 36632, 6800]*, respectively. This policy, when implemented at the distributor, has an expected total cost of 1405$ per day.
- **Scenario 2 (base case DIP):** This scenario constitutes the base case of our simulation analysis under a dual-index policy. The holding cost is set to 10 cents per punnet per day, the backordering cost is 50 cents per punnet per day, the cost of shipping 1 punnet by boat is 10 cents, the cost for shipping 1 punnet by plane is 30 cents. The solution obtained with GA sets the order-up-to-level for the regular order on Monday to *Sr=49625*, and the order-up-to-levels for the expedite orders placed from Monday to Friday to *Se=[24661, 17009, 25976, 36985, 36964, 17252]*, respectively. This policy, when implemented at the distributor, has an expected total cost of 1421.3$ per day.

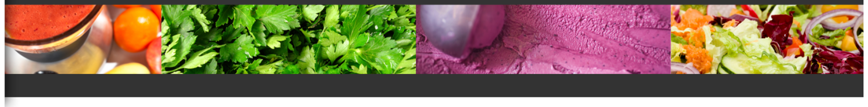



Scenarios

- **Scenario 3 (climate change COP) & Scenario 4 (climate change DIP):** In these scenarios we assume that open-air temperature at the producer is impacted by climate change. We therefore consider an open-air temperature that is normally distributed with mean 16 C and standard deviation of 3 C (vs 15 C and 2 C in the base case). Scenario 3 implements a constant order policy, while scenario 4 implements a dual-index policy under these modified temperature conditions.
- **Scenario 5 (repacking COP) & Scenario 6 (repacking DIP):** In these scenarios we assume that repacking activities impact mean and standard deviation of storage temperature at the distributor. Repacking is carried out at a temperature of 10 C. We therefore consider an overall storage temperature at the distributor that is Normally distributed with mean 3 C and standard deviation of 0.75 C (vs 1 C and 0.25 C in the base case). This modified temperature distribution accounts for the additional variation introduced by repacking activities. Scenario 5 implements a constant order policy, while scenario 6 implements a dual-index policy under these modified temperature conditions.

Scenarios

- **Scenario 7 (higher quality punnets COP) & Scenario 8 (higher quality punnets DIP):** In these scenarios we assume that the initial quality of a batch at *t*=0 is uniformly distributed in 0.3 ± 0.250 (*vs* 0.798 ± 0.709). That is we consider punnets in which 0.05 up to 0.55 percent of the strawberries are affected by Botrytis cinerea. We aim to assess the impact of higher quality products that enter the chain. Scenario 7 implements a constant order policy, while scenario 8 implements a dual-index policy under these modified initial quality conditions.
- **Scenario 9 (higher fuel costs COP) & Scenario 10 (higher fuel costs DIP):** In these scenarios, we assume that the expedite shipping cost per punnet rises to 50 cents, while the cost for regular transport is not affected. Scenario 9 implements a constant order policy, while scenario 10 implements a dual-index policy under these modified shipping costs.

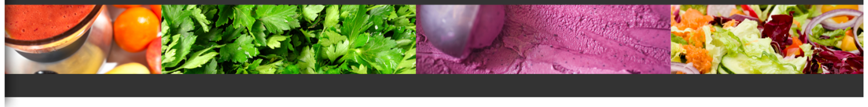


Scenarios

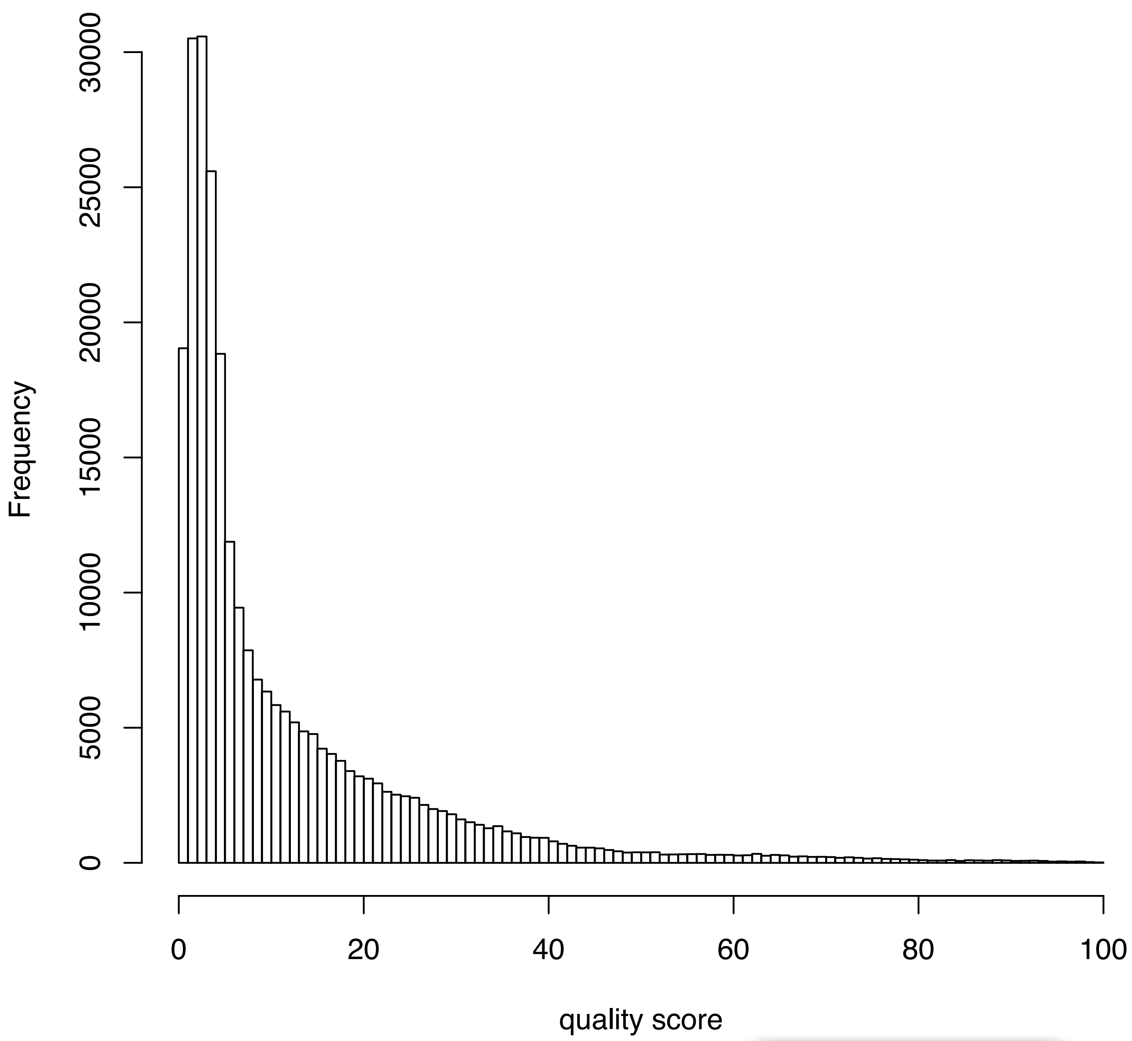
Scenarios
1 & 2 : Base
3 & 4 : Climate change
5 & 6 : Repacking
7 & 8 : Higher quality
9 & 10: Higher fuel costs

Table 1: Simulation results

	Quality at consumption		Age at consumption (hrs)		Retailer waste (punnets)	
Scenario	μ	σ	μ	σ	μ	σ
1	11.8	14.7	238	131	1477	861
2	16.9	21.4	276	166	1685	863
3	11.8	14.7	238	131	1478	863
4	16.8	21.4	276	166	1683	867
5	13.0	15.9	236	131	1577	901
6	18.3	22.2	275	166	1765	891
7	6.38	10.2	252	133	869	603
8	10.2	17.1	289	169	1102	698
9	26.2	27.2	353	196	2154	945
10	28.1	28.0	366	202	2220	963



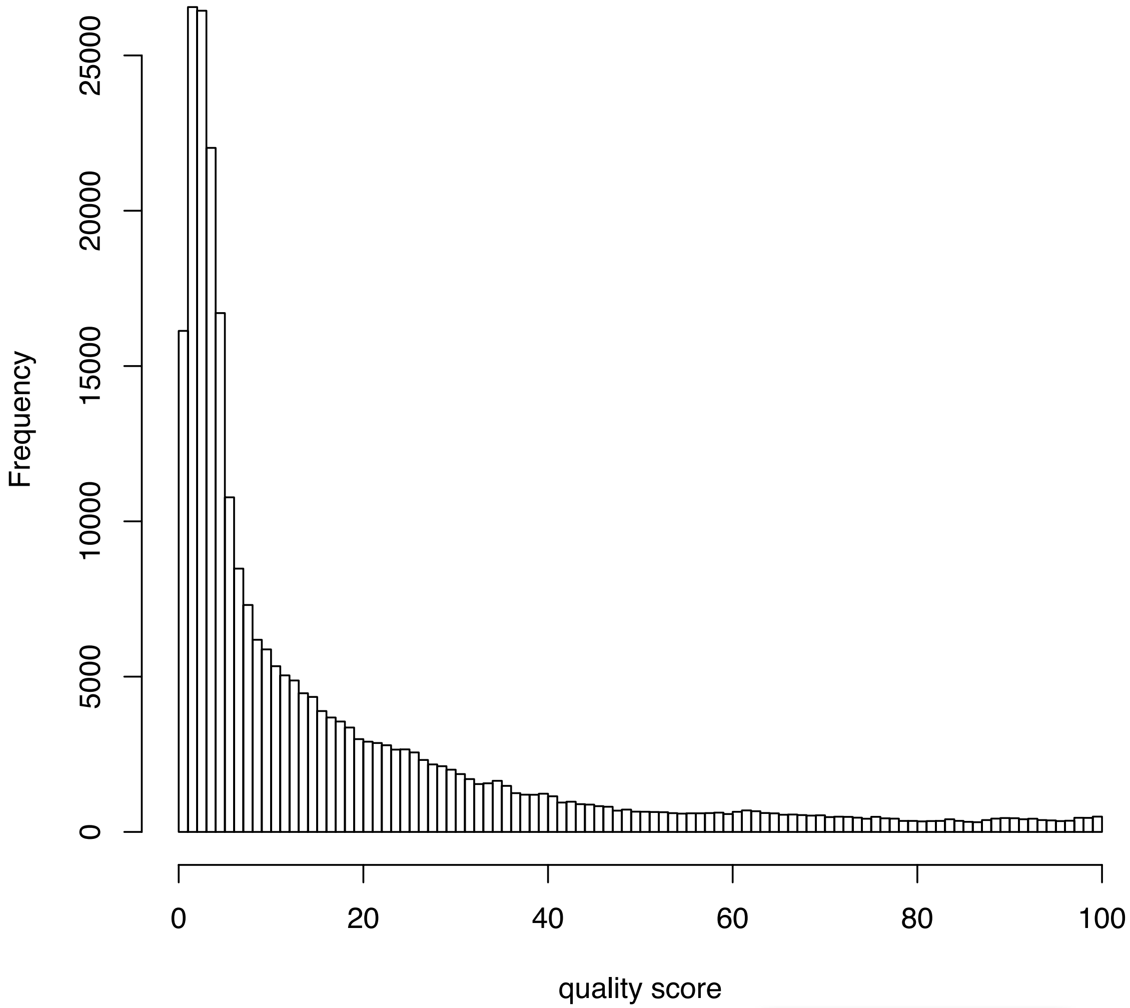
Product quality at consumption



Scenarios

1 & 2 : Base
3 & 4 : Climate change
5 & 6 : Repacking
7 & 8 : Higher quality
9 & 10: Higher fuel costs

Scenario 1



Product quality at consumption

Scenarios

1 & 2 : Base
3 & 4 : Climate change
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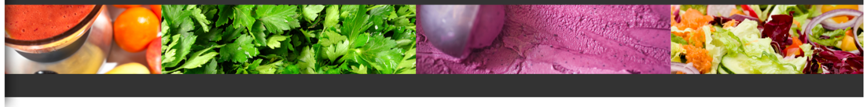
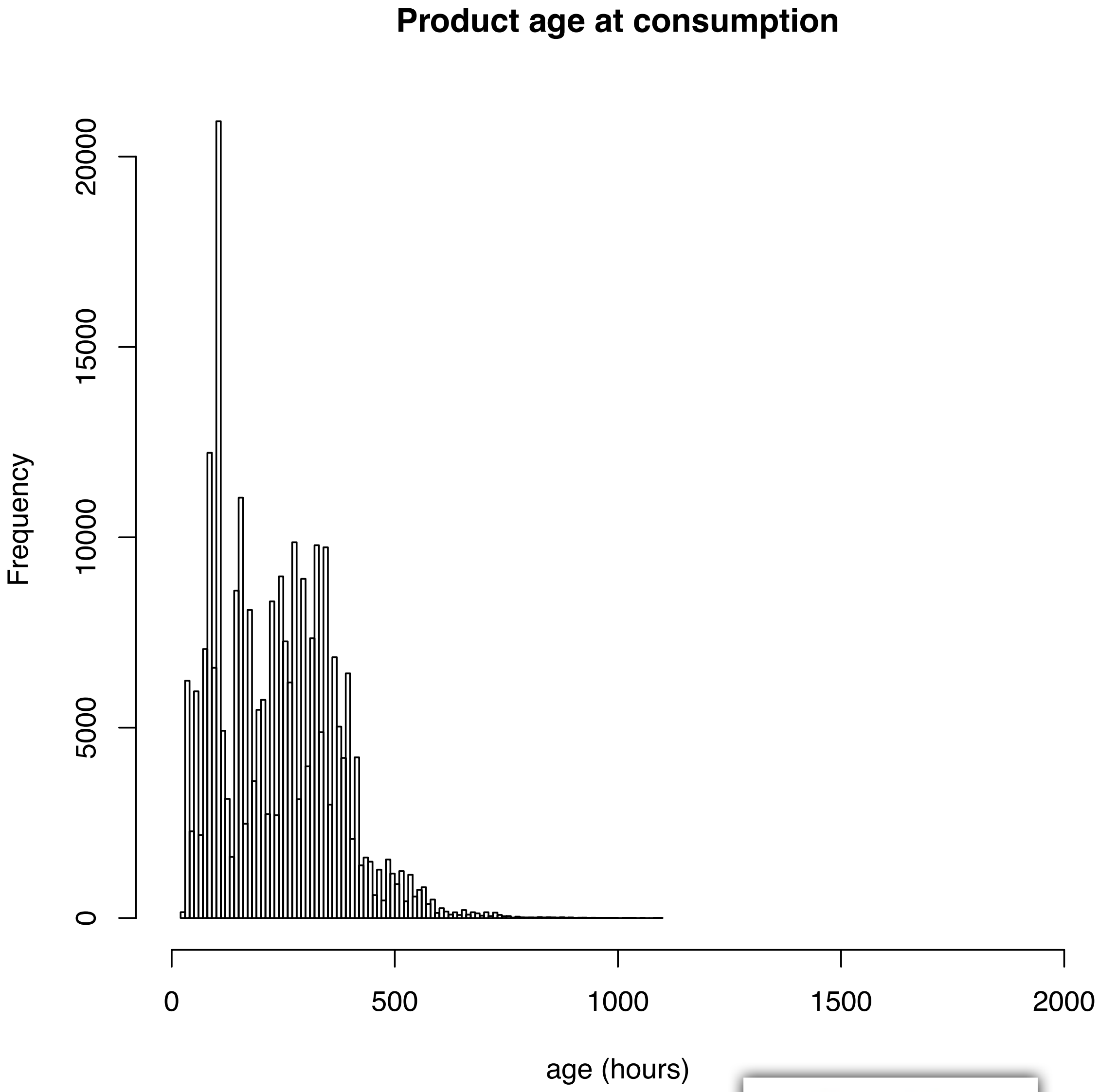
Scenario 2



Scenarios

1 & 2 : Base

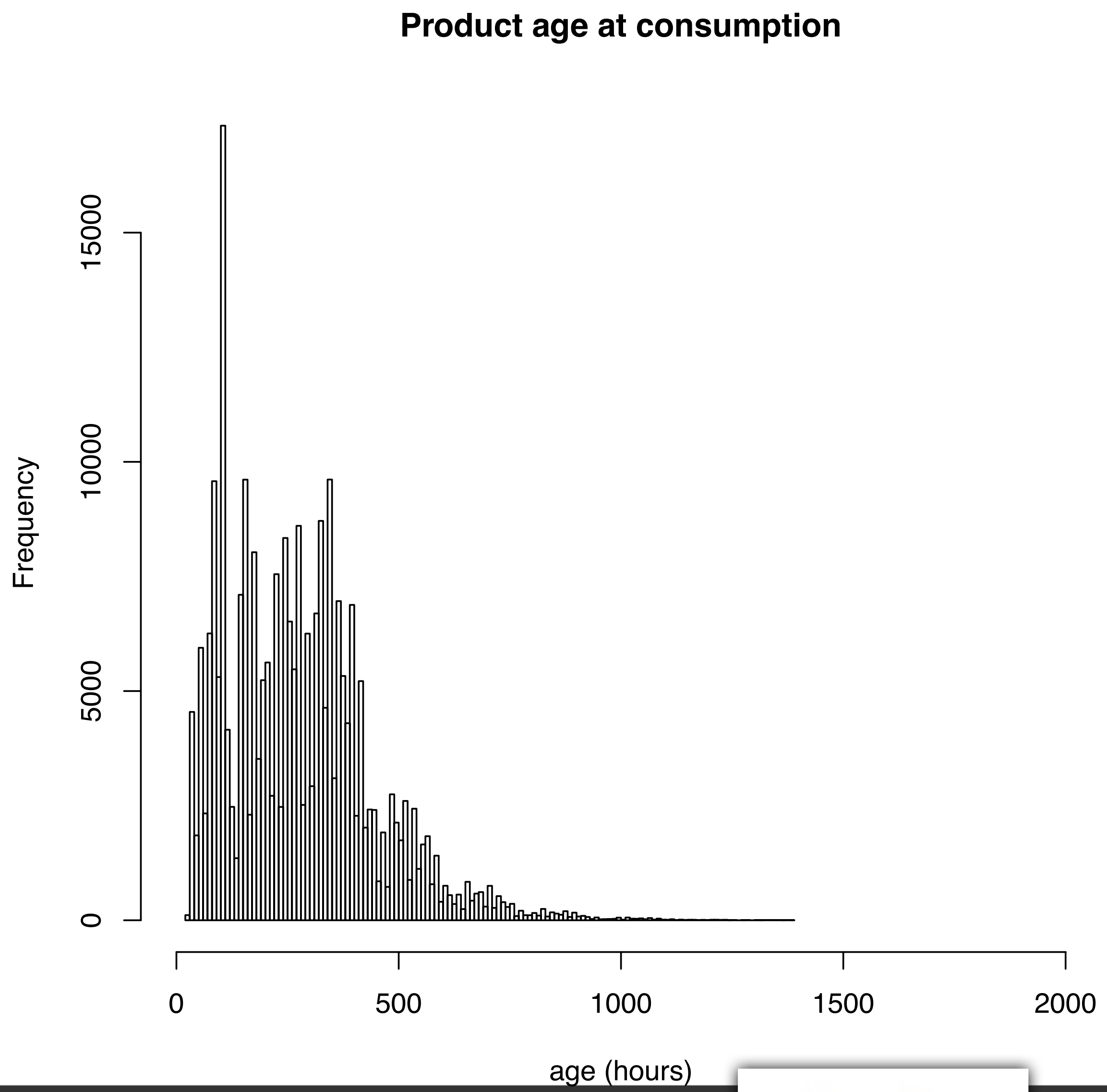
3 & 4 : Climate change

5 & 6 : Repacking

7 & 8 : Higher quality

9 & 10: Higher fuel costs

Scenario 1



Scenarios

1 & 2 : Base
3 & 4 : Climate change
5 & 6 : Repacking
7 & 8 : Higher quality
9 & 10: Higher fuel costs

Scenario 2

Quality at consumption

Scenarios
1 & 2 : Base
3 & 4 : Climate change
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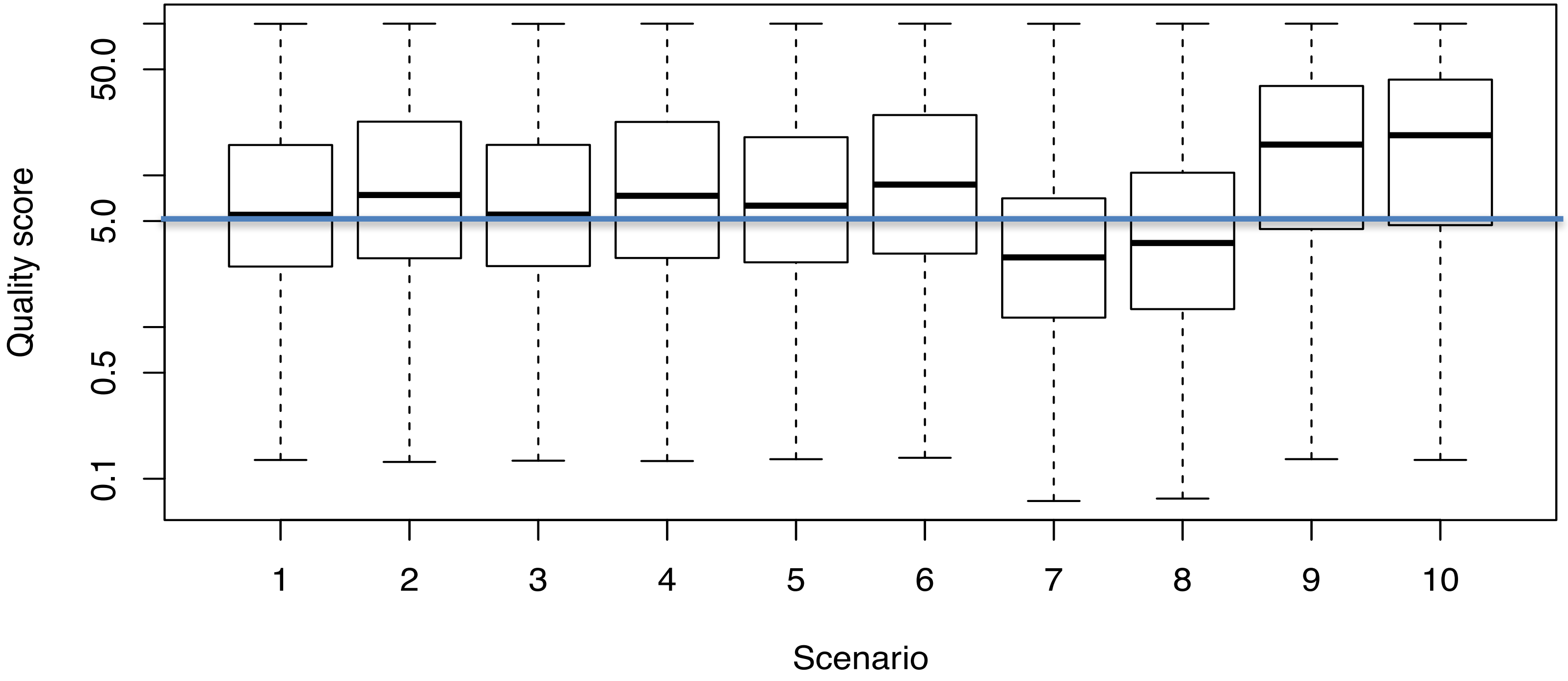
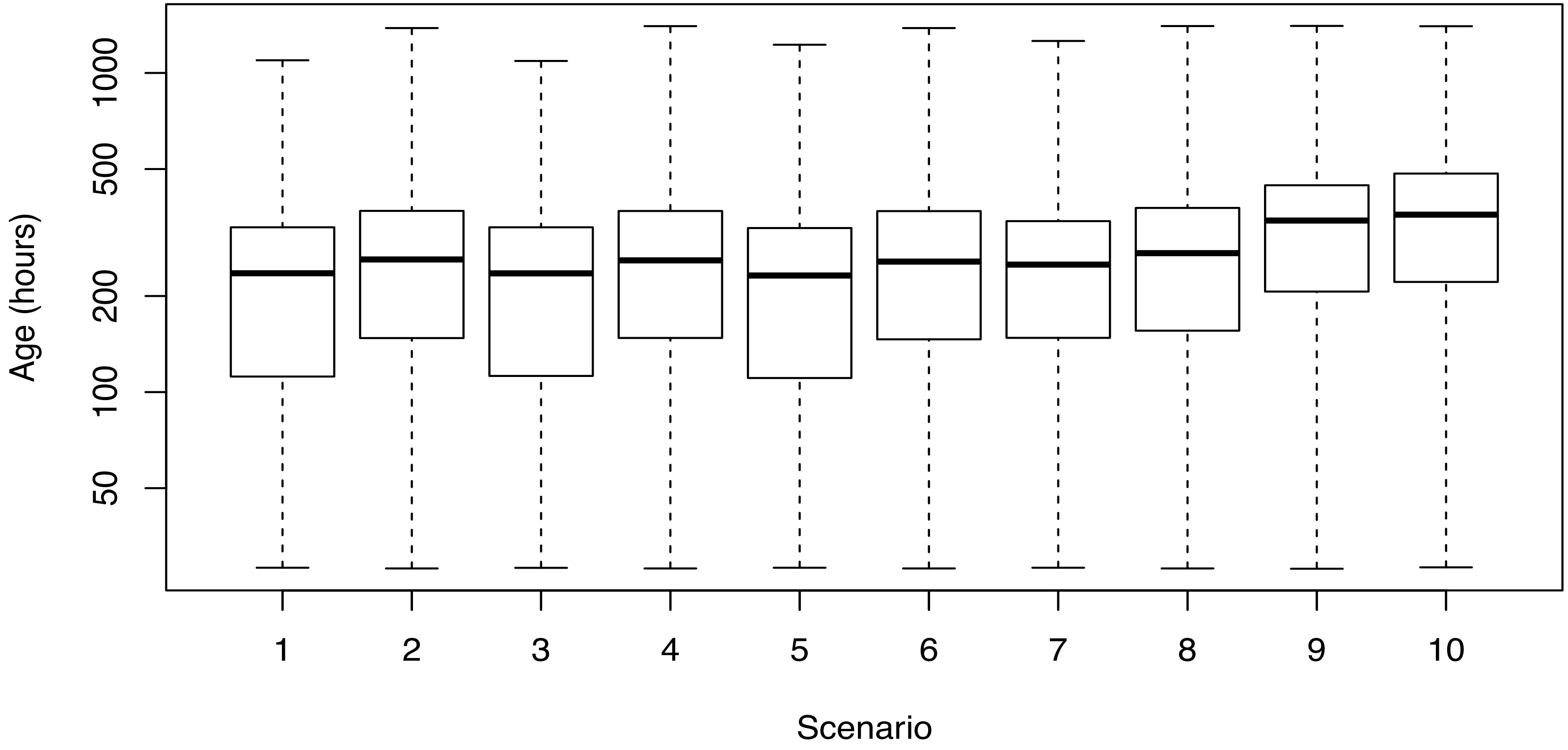


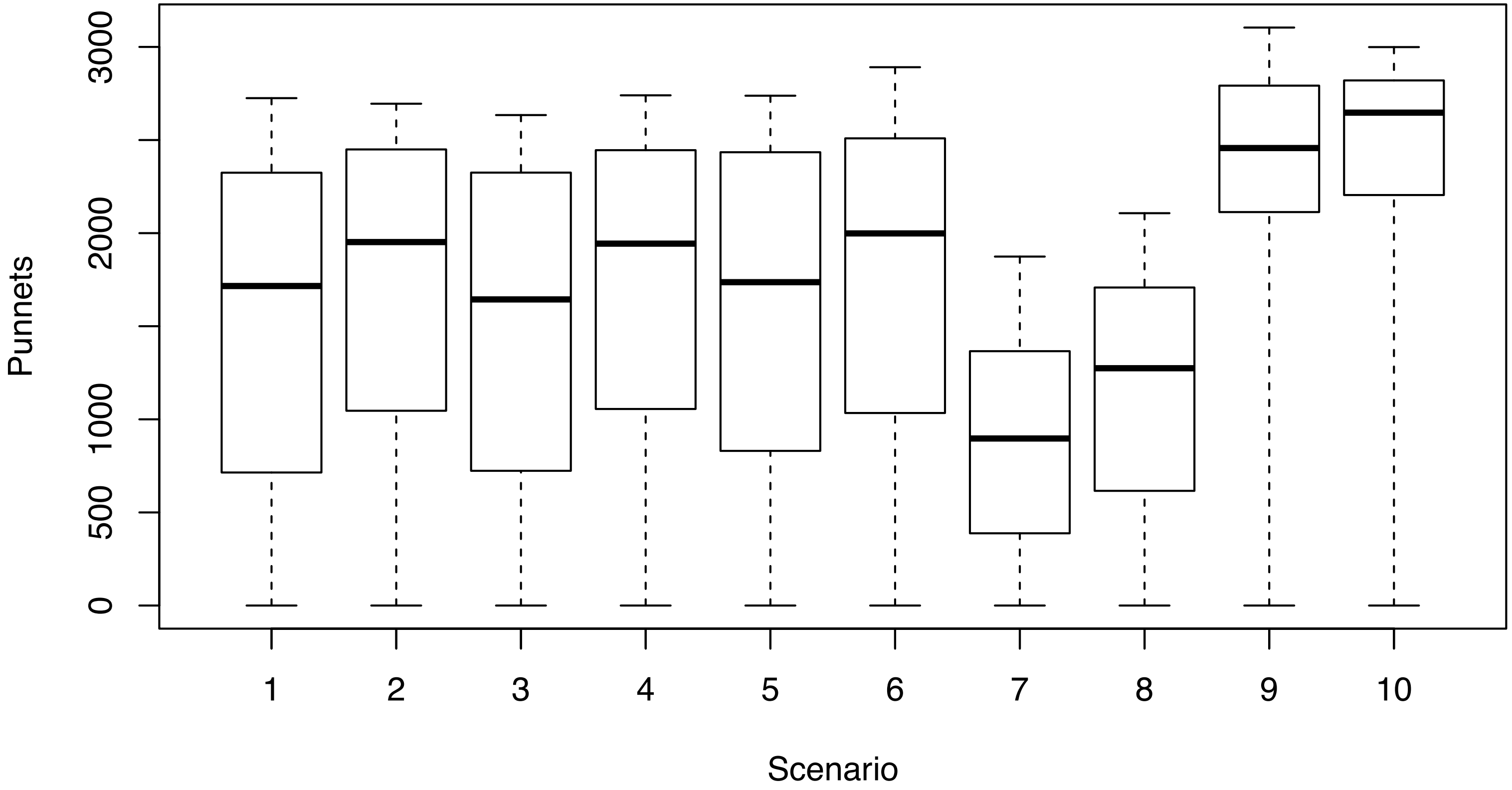
Age at consumption

Scenarios
1 & 2 : Base
3 & 4 : Climate change
5 & 6 : Repacking
7 & 8 : Higher quality
9 & 10: Higher fuel costs



Retailer waste

Scenarios
1 & 2 : Base
3 & 4 : Climate change
5 & 6 : Repacking
7 & 8 : Higher quality
9 & 10: Higher fuel costs



Conclusions

- a **dual-index policy performs poorly** compared to a constant order policy.
- an **increase** of the mean and of the standard deviation **of the open-air temperature** at the producer has only a **marginal effect** on the KPIs considered in this work.
- **Repacking activities do impact** product quality at consumption and retailer waste as demonstrated in scenario 5 and 6.
- Improved quality at the source **significantly impacts** product quality at consumption and retailer waste
- an **increase in transportation costs** for expedited shipments has **a detrimental effect on quality and waste.**
  - The management should be aware that in such a situation, **a mere optimization of the expected total cost of running the chain represents a poor strategy**.
  - Any optimization model employed should **carefully strike a balance between cost reduction and quality loss** due to the **increase of products shipped via regular orders**.

Future work

- Impact of **controlled atmosphere** in the warehouse is not taken into account.
  - Products are typically stored under **modified CO2 concentrations** that tend to **reduce or even stop** mold growth.
  - Advanced model for strawberry quality include the effect of CO2 concentration. In this sense, **results presented may be seen as worst-case scenarios,** since in a modified atmosphere, mold growth will be significantly slower.
- the **optimization algorithms** adopted for computing near-optimal inventory control policy parameters **are heuristics**.
  - Future works may **investigate** difference observed when an **optimal control policy** is implemented.
  - a **challenging area for further research** is the development of **optimization models for dual sourcing that include service level constraints** involving product quality.
- a thorough **validation of the results** here presented should be carried out to validate the model and to calibrate its parameters against the actual operating conditions of the chain.

SEVENTH FRAMEWORK
PROGRAMME

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