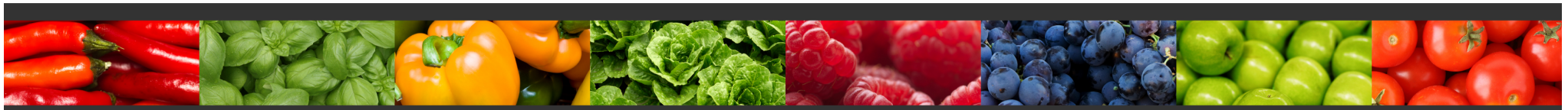
Dual Sourcing in Food Supply Chain Networks: the case of Egyptian strawberries

Dr. Roberto Rossi

SEVENTH FRAMEWORK PROGRAMME

veg-i-trade

safe food for a changing world



The Veg-i-Trade Project (2010-2014)

"Global trade with stakeholders in many different countries makes the management of food safety extremely difficult." http://www.veg-i-trade.org/

Concerns have emerged regarding the safety of fresh produce in response to recent outbreaks and alerts linked to fresh produce and derived food products:

- Irish pork recall 2008
- Germany E. coli O104:H4 outbreak 2011

The Veg-i-Trade Project (2010-2014)

Objective: Veg-i-Trade will develop control measures of a managerial and technological nature in the supply chain of crop production, post-harvest processing and logistics to minimize food safety risks.

Numbers:

- 23 international partners (12 academic, 11 industrial)
- 10 countries involved

Workpackages

Mapping of the economical structure and organisation of the fresh produce supply chain at European and global levels and the identification of new trends in European consumption patterns
> WP1

Development and validation of diagnostic instruments as a tool for the systematic assessment of the performance of Horticulture Safety Management Systems in the fresh produce chain
> WP2

Formulation of adaptation scenarios of 'Horticulture Safety Management Systems' to anticipate globalisation and climate change, leading to the description of Quality Assurance (QA) recommendations on EU and global levels
> WP3

Study of the pre- and post-harvest conditions, including agronomical cultural practices and further processing techniques, packaging and storage conditions, on plant physiology and microbial ecology of fresh produce
> WP 4

Modeling of water treatment technology with respect to the adequacy of the microbiological quality of water used in the fresh produce supply chain and evaluation of production of chemical by-products
> WP5

Elaboration of useful recommendations regarding the application of good practices in the fresh produce supply chain to improve the adequacy and operation of control measures to prevent and/or reduce microbiological and chemical hazards
> WP 6 | WP 7 | WP 8

Development of risk-based sampling plans, risk ranking and definition of risk-based metrics by microbiological and chemical risk assessments of fresh produce and derived food products, consumed in Europe, taking into consideration effects of packaging, logistics and globalization.
> WP 6 | WP 7 | WP 8

Exploration of new and emerging food contamination pathways for microbiological and chemical hazards by baseline surveys, simulation and modeling of the logistic chain and risk assessments
> WP 6 | WP 7 | WP 8

Elucidation of trends affecting the health risks in the fresh produce supply chain related to changes in crop productivity patterns due to plausible future climate scenarios for major European regions and the world as a whole
> WP9

Risk communication in order to respect the principle of food sovereignty in the setting of risk management strategies
> WP10

Strengthening international collaboration by scientific cooperation, exchange of information and capacity building between trade partners in fresh produce in a global food market
> WP 10 | WP 11

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The Team

J.G.A.J van der Vorst, Wageningen University, Professor of Logistics Management

R. Rossi, Wageningen University, Assistant Professor, University of Edinburgh, Lecturer in Management Science

F. Lopez-Galvez, Postdoctoral Researcher, University of Ghent, Belgium

W.A. Rijpkema, Wageningen University, PhD candidate (now supply chain manager at FrieslandCampina)

…and many others colleagues from Veg-i-Trade!

Publications (selection)

R. Rossi, J. Van der Vorst, L. Jacxsens and M. Uyttendaele, "**The Impact of Advanced Inventory Control Policies on Quantitative Microbiological Risk Assessment in Food Supply Chains**", working paper

W. A. Rijpkema, R. Rossi, F. Lopez-Galvez, J.G.A.J van der Vorst, "**Use of form postponement in the reduction of food waste under product quality decay**", accepted with minor revisions to the International Journal of Logistics Research and Applications, 2015

W. Rijpkema, R. Rossi and J. Van der Vorst, "**Effective sourcing strategies for perishable product supply chains**", International Journal of Physical Distribution & Logistics Management, Emerald, Vol. 44(6):494-510, 2014

R. Rossi, "**Periodic review for a perishable item under nonstationary stochastic demand**", in Bakhtadze, Natalia, Chernyshov, Kirill, Dolgui, Alexandre, Lototsky, Vladimir Editors, Proceedings of the IFAC Conference on Manufacturing Modeling, Management and Control, MIM 2013, June 19-21, 2013, Saint Petersburg, Russia, International Federation of Automatic Control, Manufacturing Modelling, Management, and Control, Volume 7(1), pp. 2021-2026, 2013

W.A. Rijpkema, R. Rossi, J.G.A.J van der Vorst, "**Logistics management strategies to improve food safety of fresh fruits at retail outlets: the case of year-round sourcing of strawberries**", in Proceedings of the 7th International European Forum (Igls-Forum) - (136th EAAE Seminar) on System Dynamics and Innovation in Food Networks, February 18-22, 2013 - Innsbruck-Igls, Austria

R. Rossi, W. Rijpkema and J.G.A.J van der Vorst, "**The impact of dual sourcing on food supply chain networks: the case of Egyptian strawberries**", in Proceedings of the 11th Wageningen International Conference on Chain and Network Management (WICaNeM 2012), 23-25 May 2012, Wageningen, The Netherlands

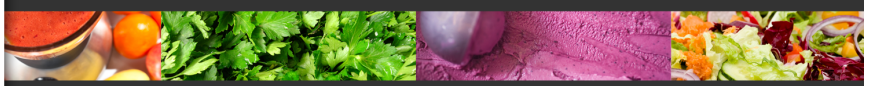
Two Key Concerns

Veg-i-Trade focused on two key aspects:

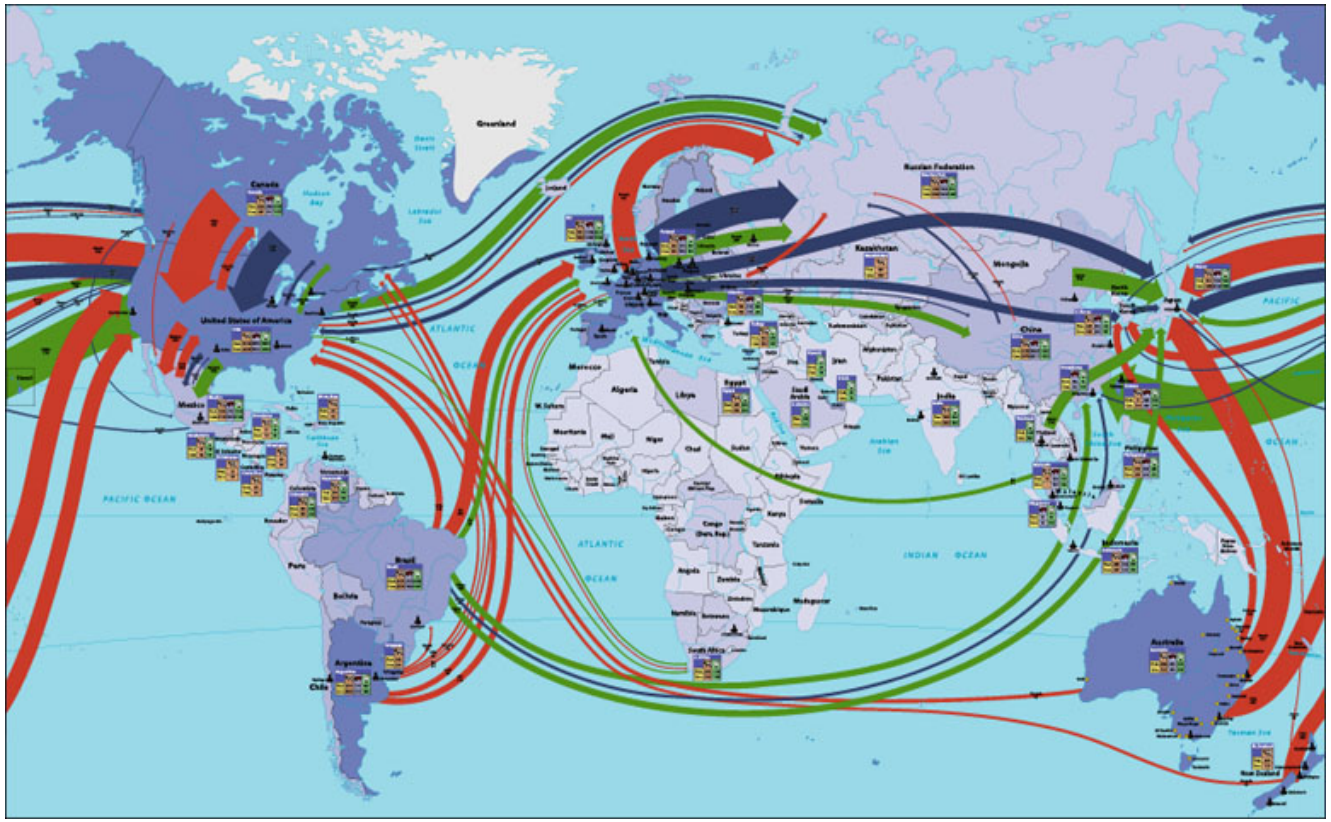
Quality of products

Safety of products

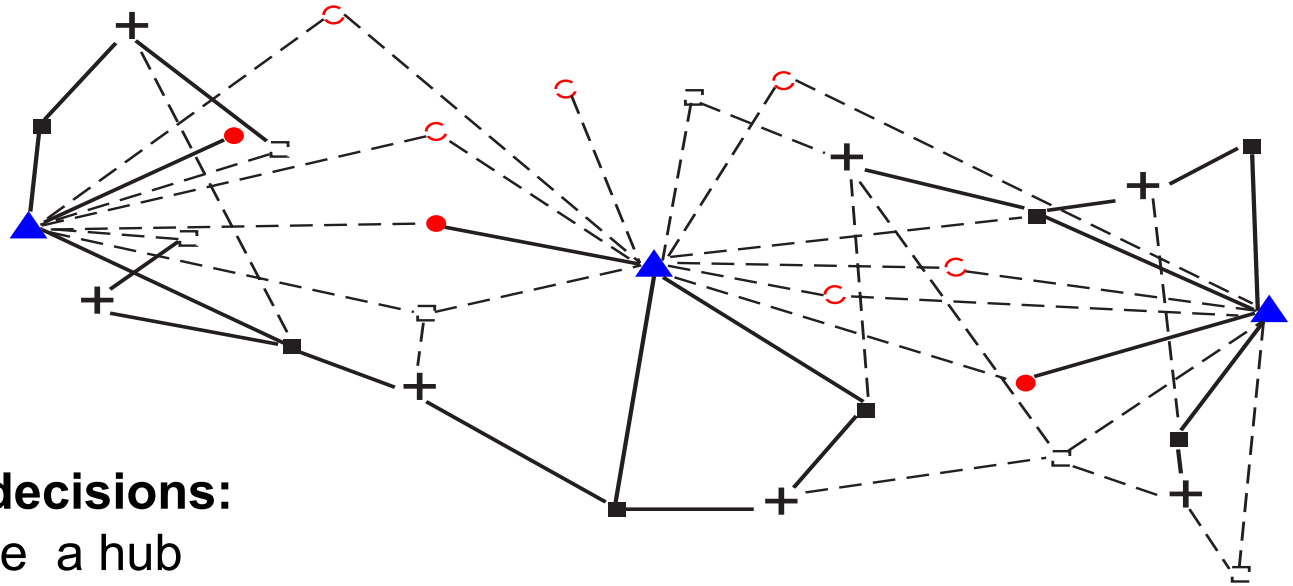
traded in global food supply chain networks.



Global supply chain network

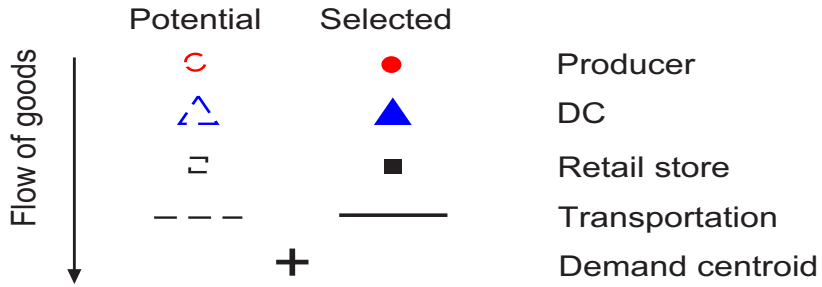


Decision support system



Strategic decisions:

- open/close a hub
- produce/not produce
- serve a given area
- …



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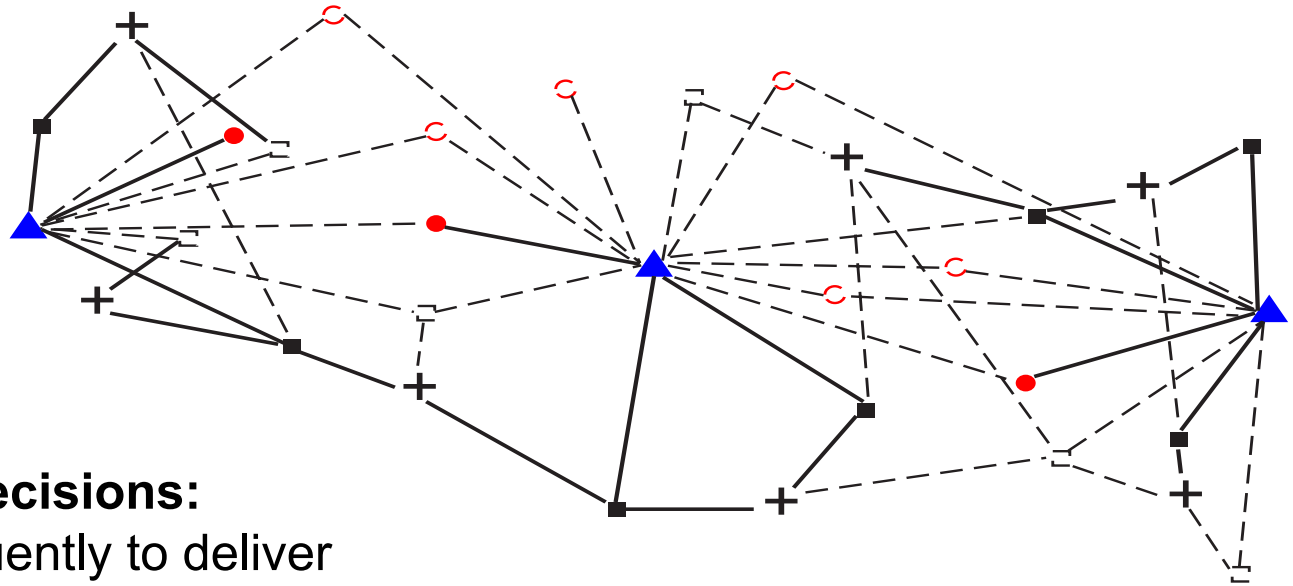
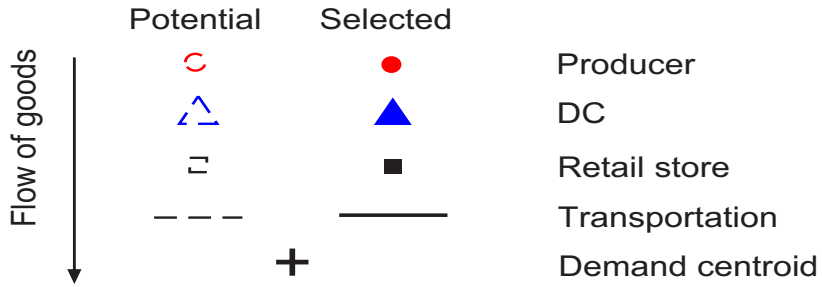


Tactical decisions:
- how frequently to deliver
- production cycles
- target stock level at hub
- …



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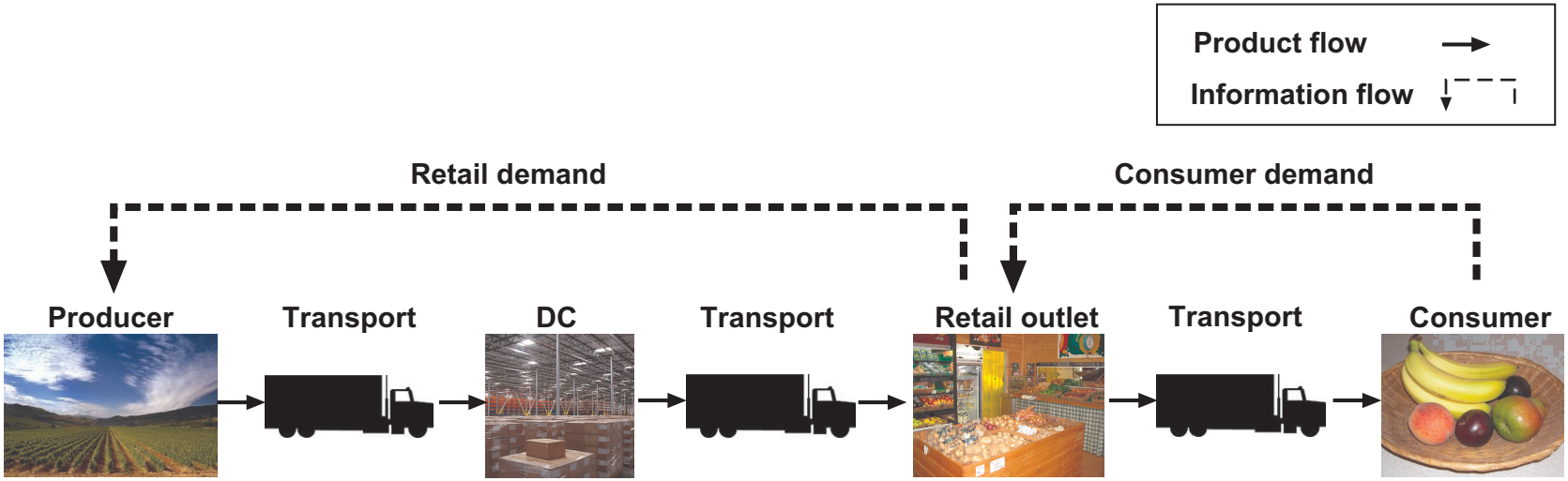
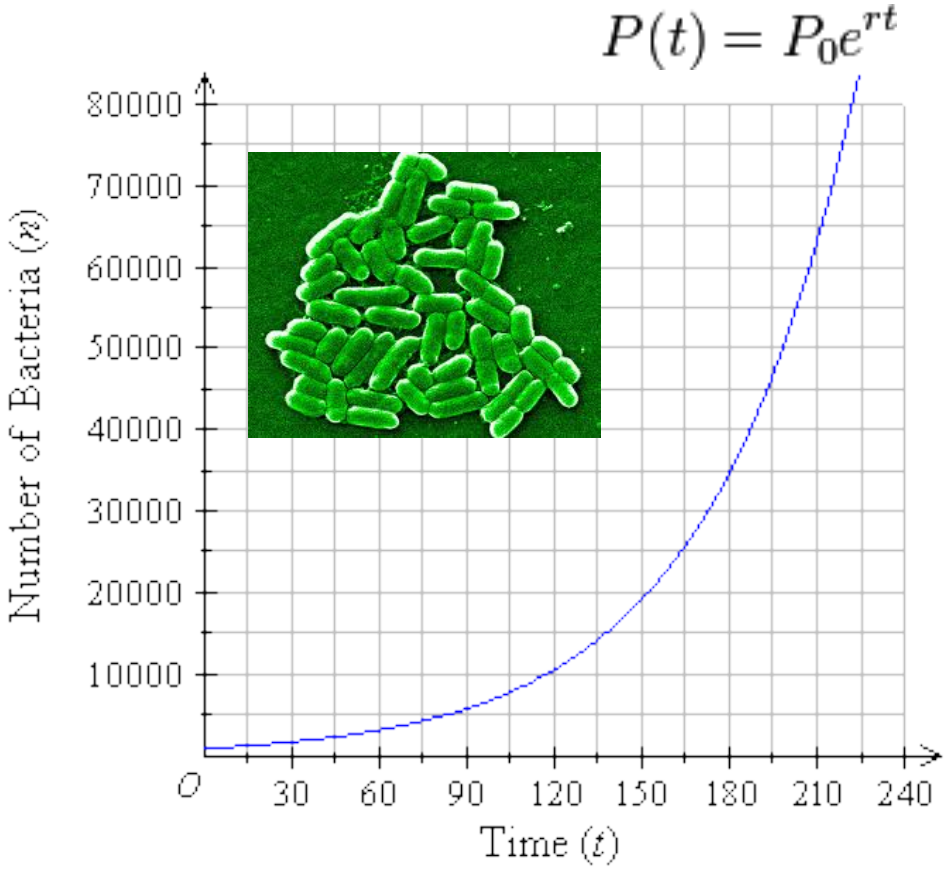


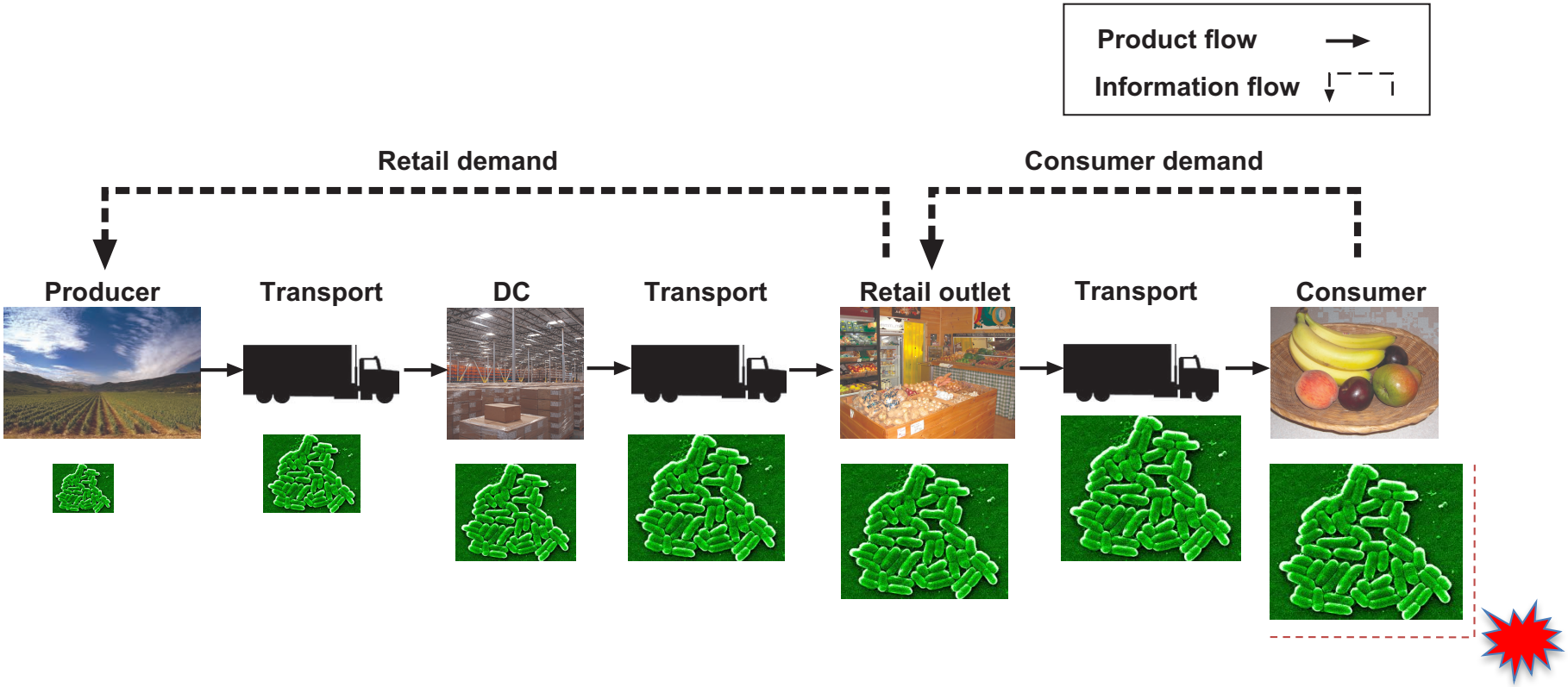
Operational decisions:

- production quantity on a given day
- order quantity at DC
- truck load from DC to Retail outlet

Quality/Safety change models

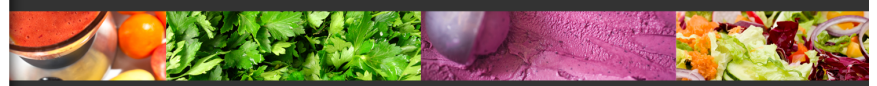


A global logistic chain



Impact of Dual Sourcing on Fruit Quality

- We investigated the **impact of dual sourcing strategies** on **quality** of **fresh fruit** traded in international **food supply chains**.
  - W. Rijpkema, R. Rossi and J. Van der Vorst, "**Effective sourcing strategies for perishable product supply chains**", International Journal of Physical Distribution & Logistics Management, Emerald, Vol. 44(6):494-510, 2014
- 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.

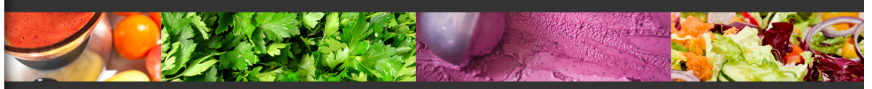
- An interesting issue then is to study **if dual sourcing**, which is a common strategy among firms to reduce costs, **may jeopardize product quality** in food supply chains.

Research questions

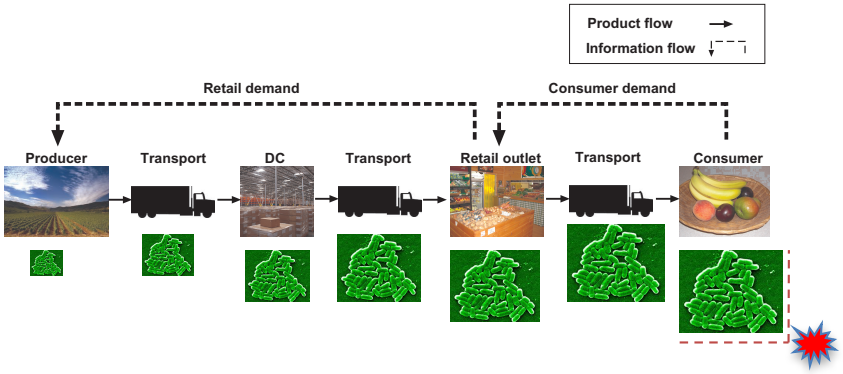
1. Does a dual sourcing inventory control policy, whilst reducing costs, **guarantee a sufficient quality** at consumption and reasonable waste?

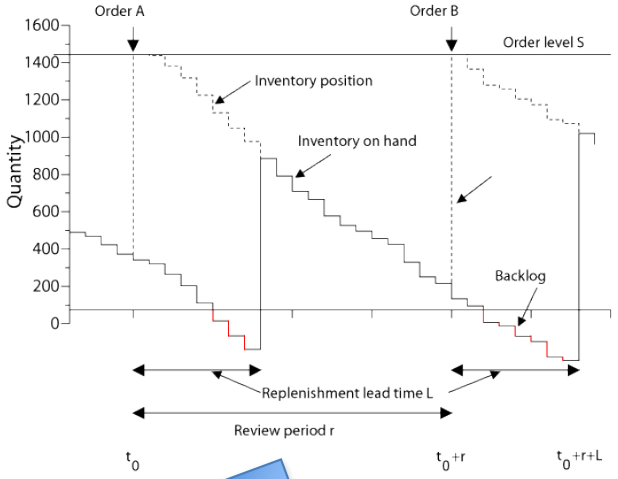
2. How **sensitive** is a dual sourcing policy to **variations of initial quality and temperatures** along the chain?

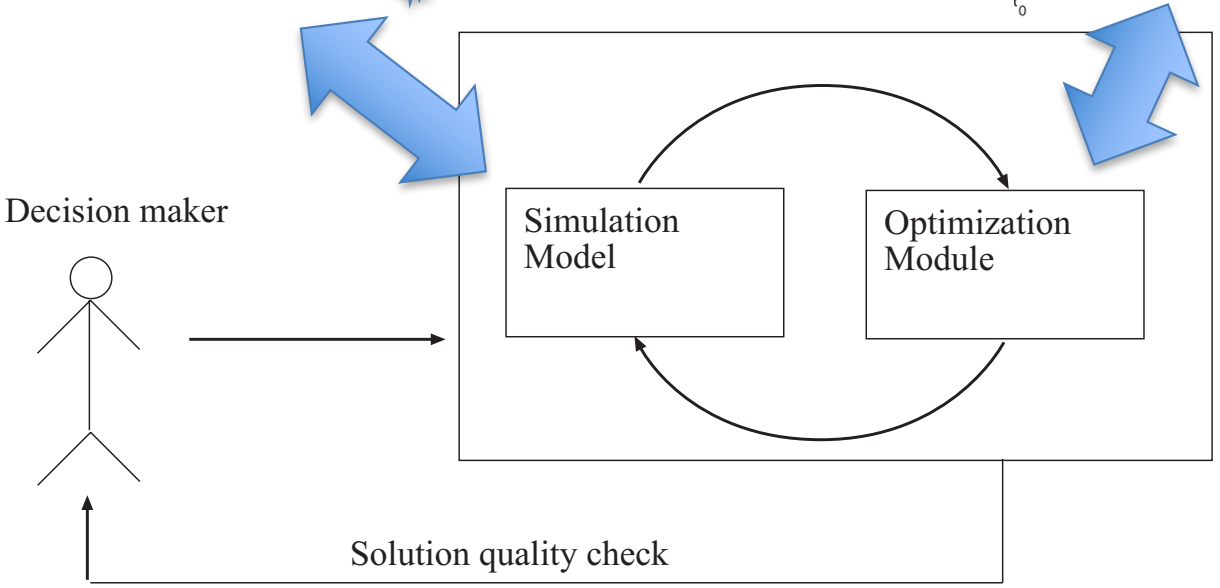
3. What is the **impact of fuel cost** variation on final product **quality** and on **waste**?



Methodlogy: hybrid simulation/optimization approach



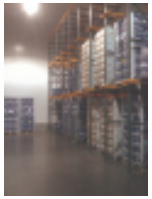




Case: fresh strawberries

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

Strawberry supply chain sourcing areas and distribution center



SPECIAL FRUIT

Strawberry supply chain sourcing areas and distribution center

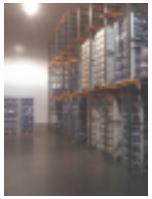
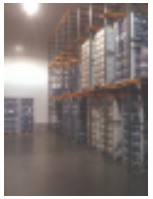


Table 1: Import regions of strawberries for different seasons

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



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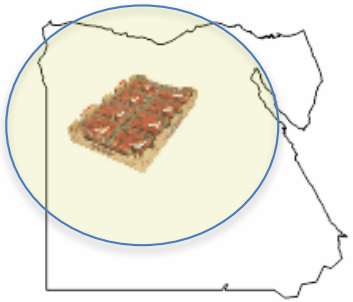
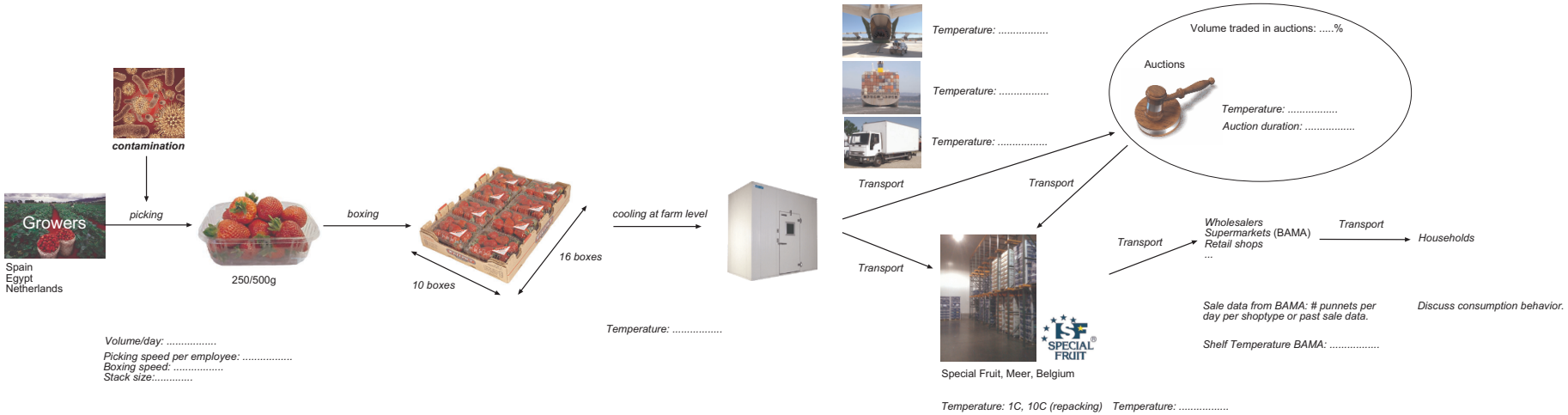


General Chain (Strawberries)



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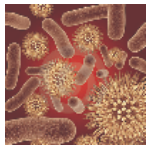


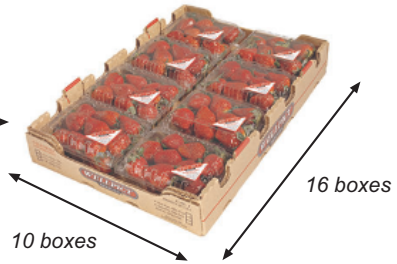
contamination

Spain
Egypt
Netherlands

picking

250/500g

boxing



cooling at farm level

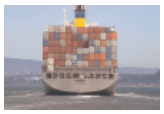
Temperature: .....

Volume/day: .....

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

General Chain (Strawberries)

Temperature: .....



Temperature: .....

Temperature: .....

Volume traded in auctions: .....%

Auctions

Temperature: .....

Auction duration: .....

Transport

Transport

Transport

Special Fruit, Meer, Belgium

Temperature: 1C, 10C (repacking)

Temperature: .....

Transport

Wholesalers
Supermarkets (BAMA)
Retail shops
...

Transport

Households

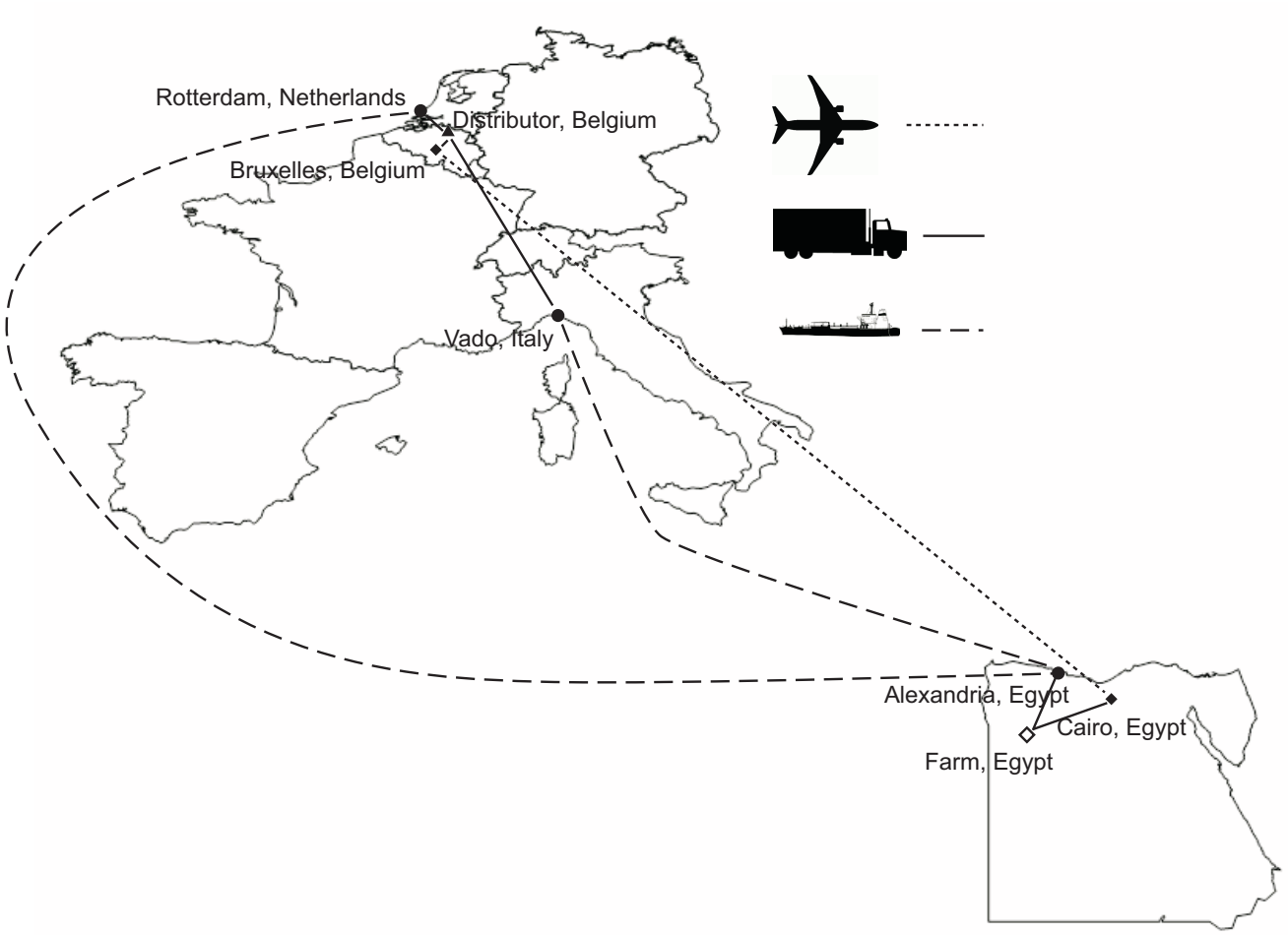
Sale data from BAMA: # punnets per day per shoptype or past sale data.

Discuss consumption behavior.

Shelf Temperature BAMA: .....

....

Egypt - Netherlands Supply Chain (Strawberries)



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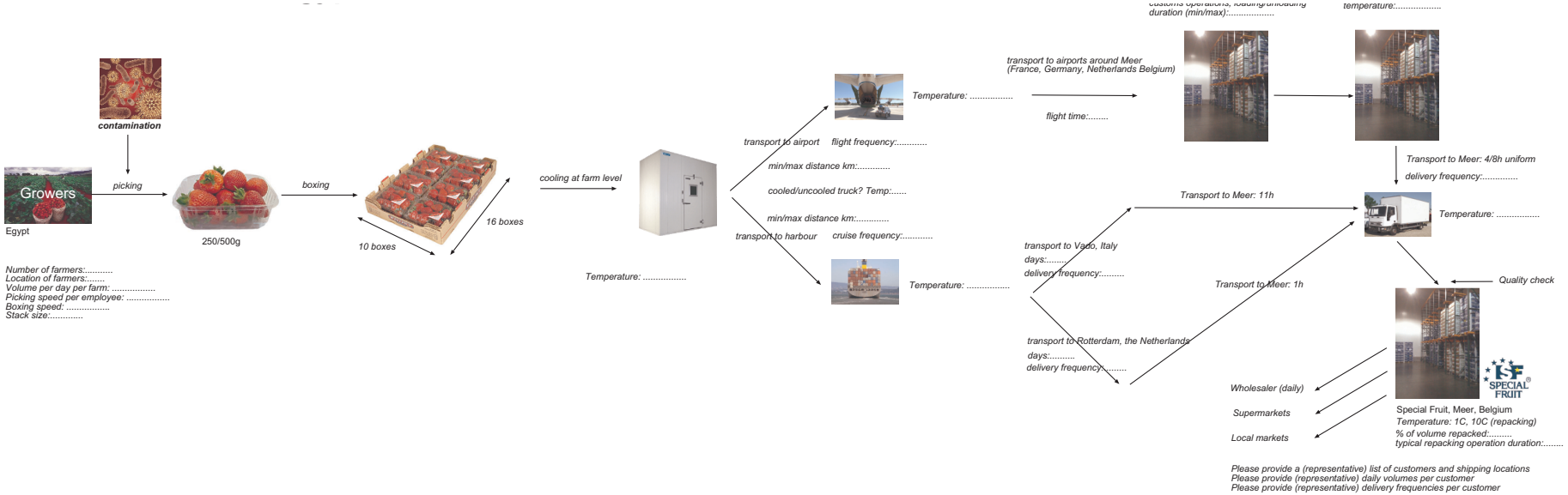

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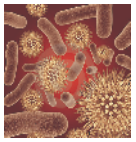


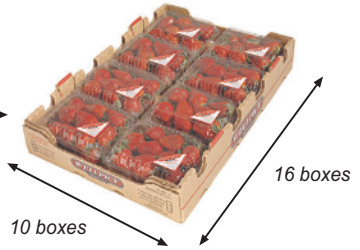
contamination

Egypt

picking

250/500g

boxing



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: .....

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: .....

Quality check

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

Transport to Meer: 11h

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

Transport to Meer: 1h

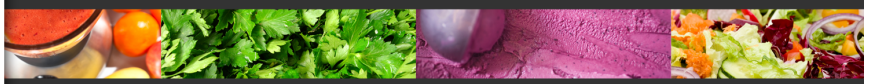
Special Fruit, Meer, Belgium
Temperature: 1C, 10C (repacking)
% of volume repacked:.....
typical repacking operation duration:.....

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!

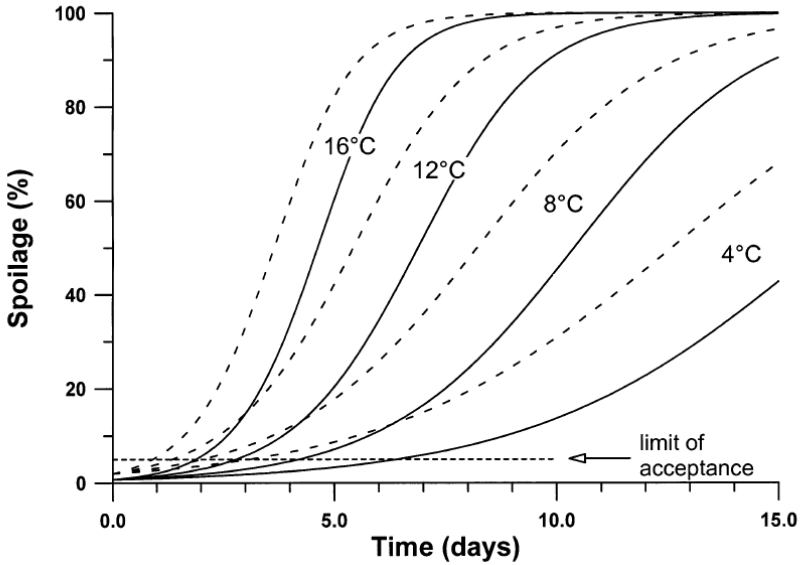
Problem parameters

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

Quality (Strawberries)

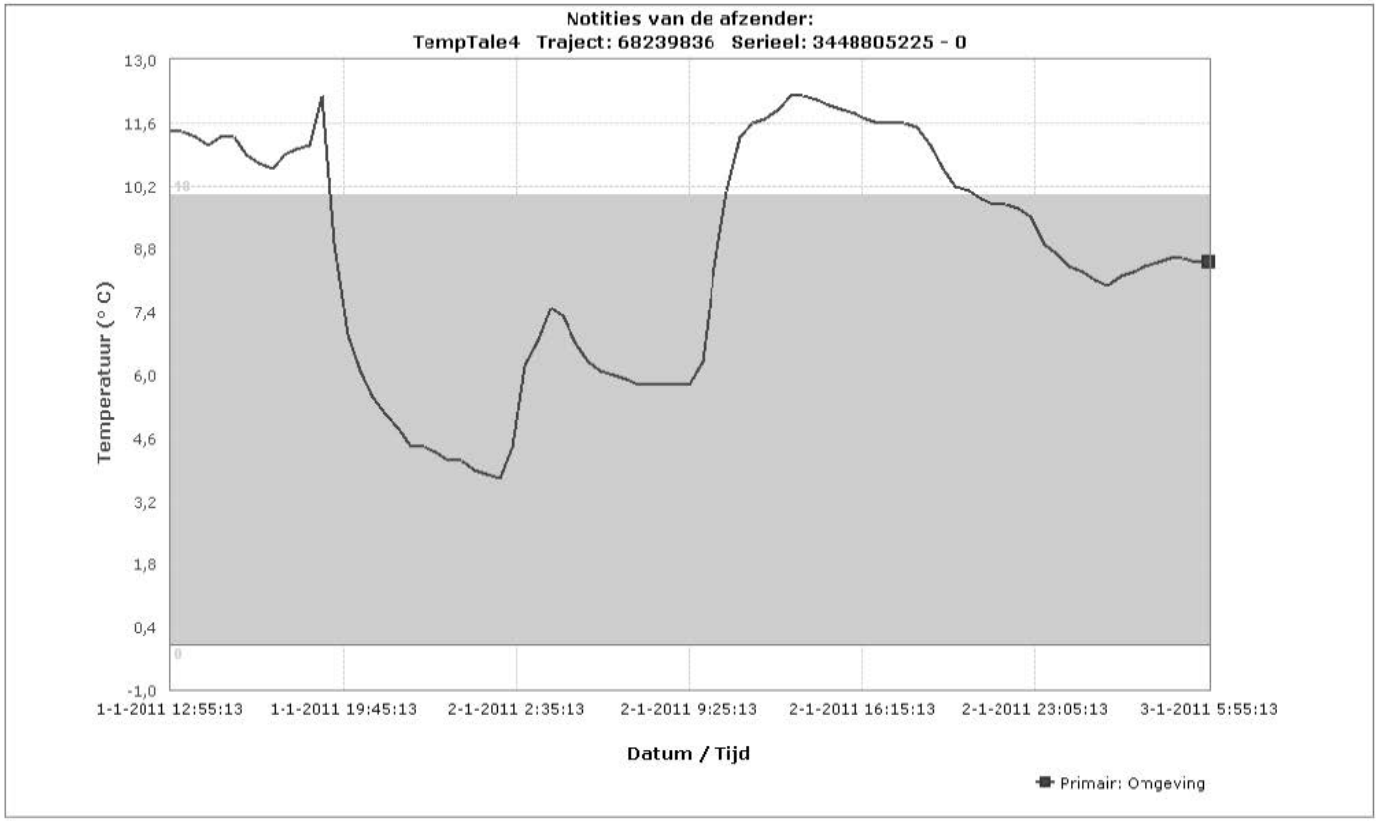
- Botrytis cinerea in strawberries (Hertog et al 1999)

Qto=0.1



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

Temperature profiles



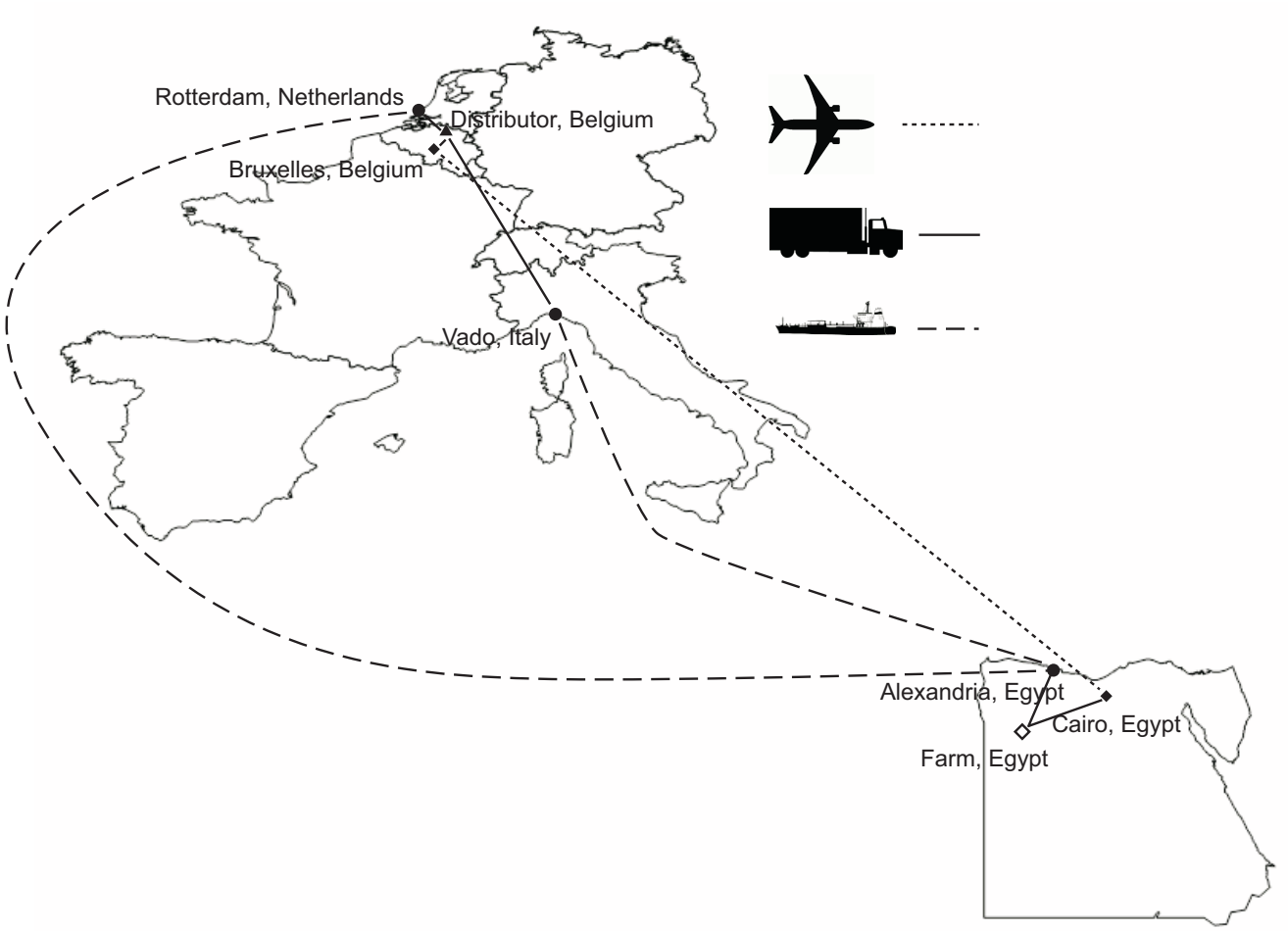
Eerste geregistreerde punt:
1-1-2011 12:55:13

Laatste geregistreerde punt:
3-1-2011 5:55:13

Weergegeven: 83 punten

Opmerkingen:
E:\kwaliteit\temperatuur recorders\temptale\Magrabi\2011\68239836_3448805225_0 magrabi.ttx - Afgedrukt 31-1-2011 14:28:00

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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ABSTRACT

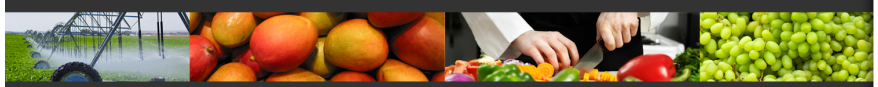
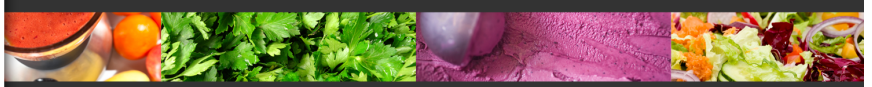
We analyze a single-product, periodic-review, stochastic demand inventory model with backorders and two supply options, a regular and a more expensive expedited one, with deterministic, offsetting lead times. Since the optimal policy for such a problem is generally unknown, several simpler policies have 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

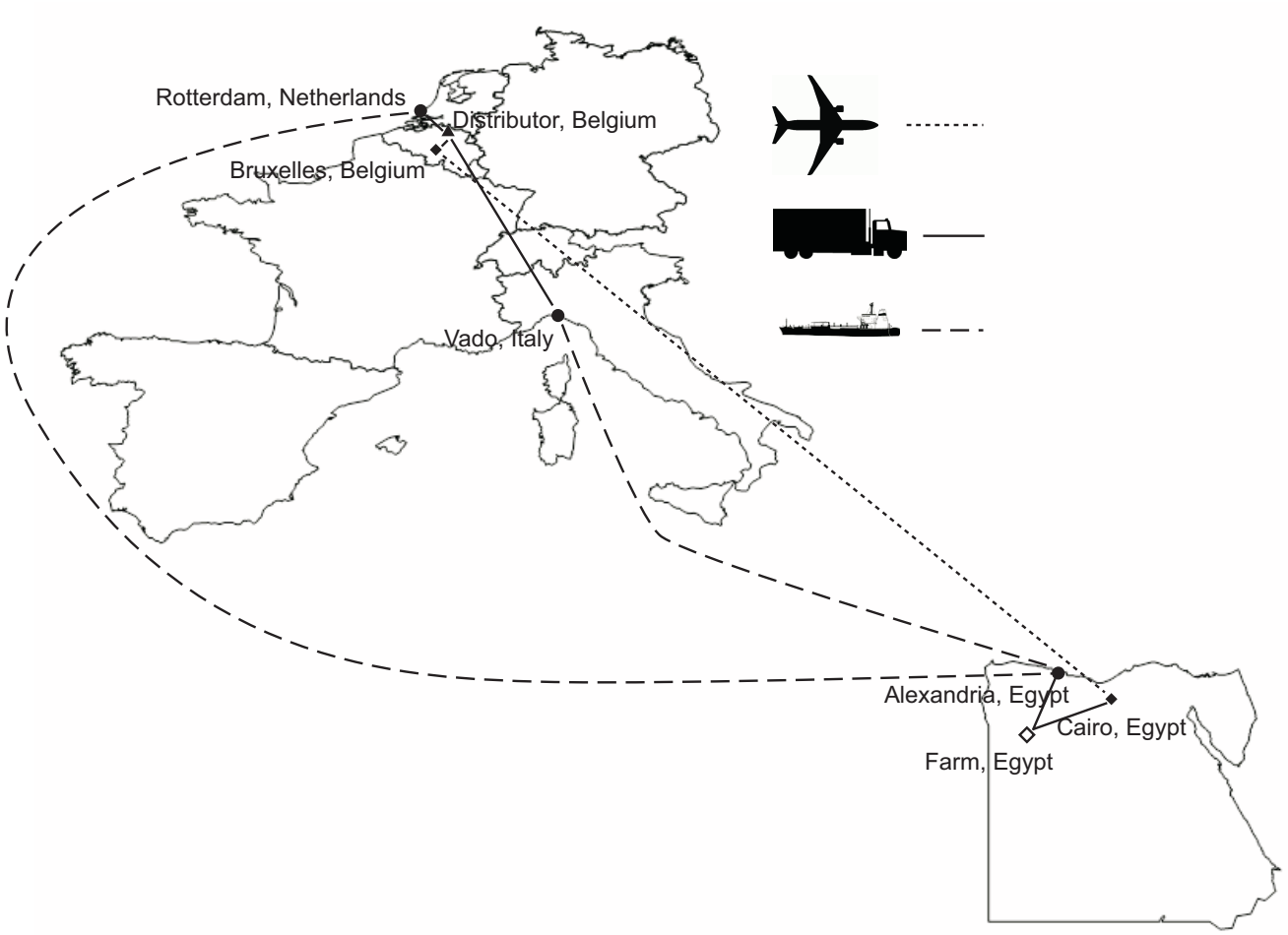
- JGAP (Java Genetic Algorithm Package)

- 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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Safety Stock Positioning in Supply Chains with Stochastic Lead Times

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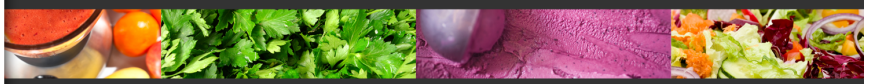
We study the safety stock positioning problem in single-product multistage supply chains with tree network structures, where each stage controls its inventory using an installation continuous-time base-stock policy. External demands follow independent Poisson processes, and unsatisfied demands at each 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 top[illegible] approximations and algorithms to coordinate

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. 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. 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 as opposed 0.8 ± 0.7 *in the base case*.

  That is we consider punnets in which 0.0005 up to 0.0055 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, 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

Scenarios

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

Heavy tailed system! Figures not very enlightening.

Table 1: Simulation results

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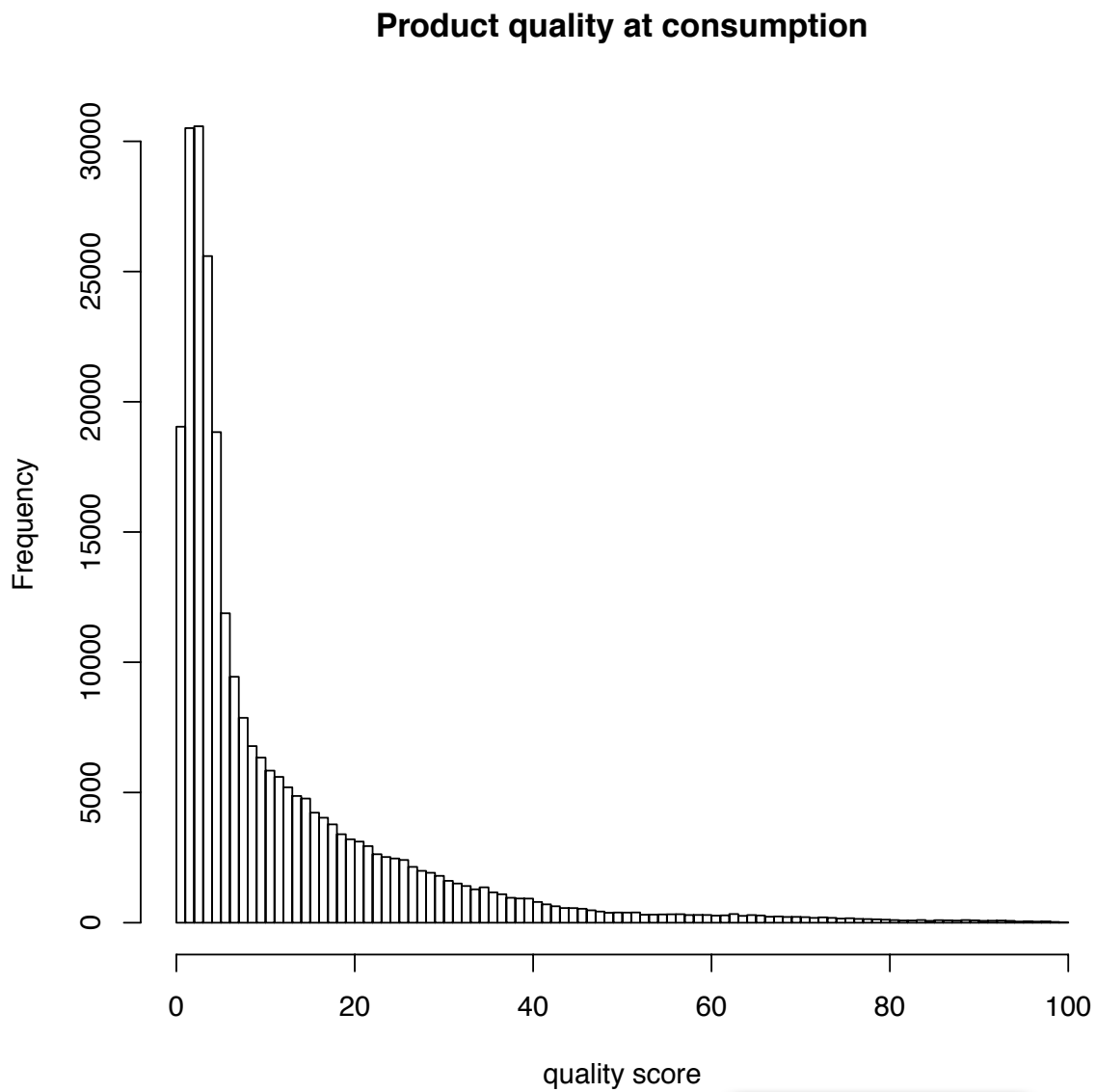
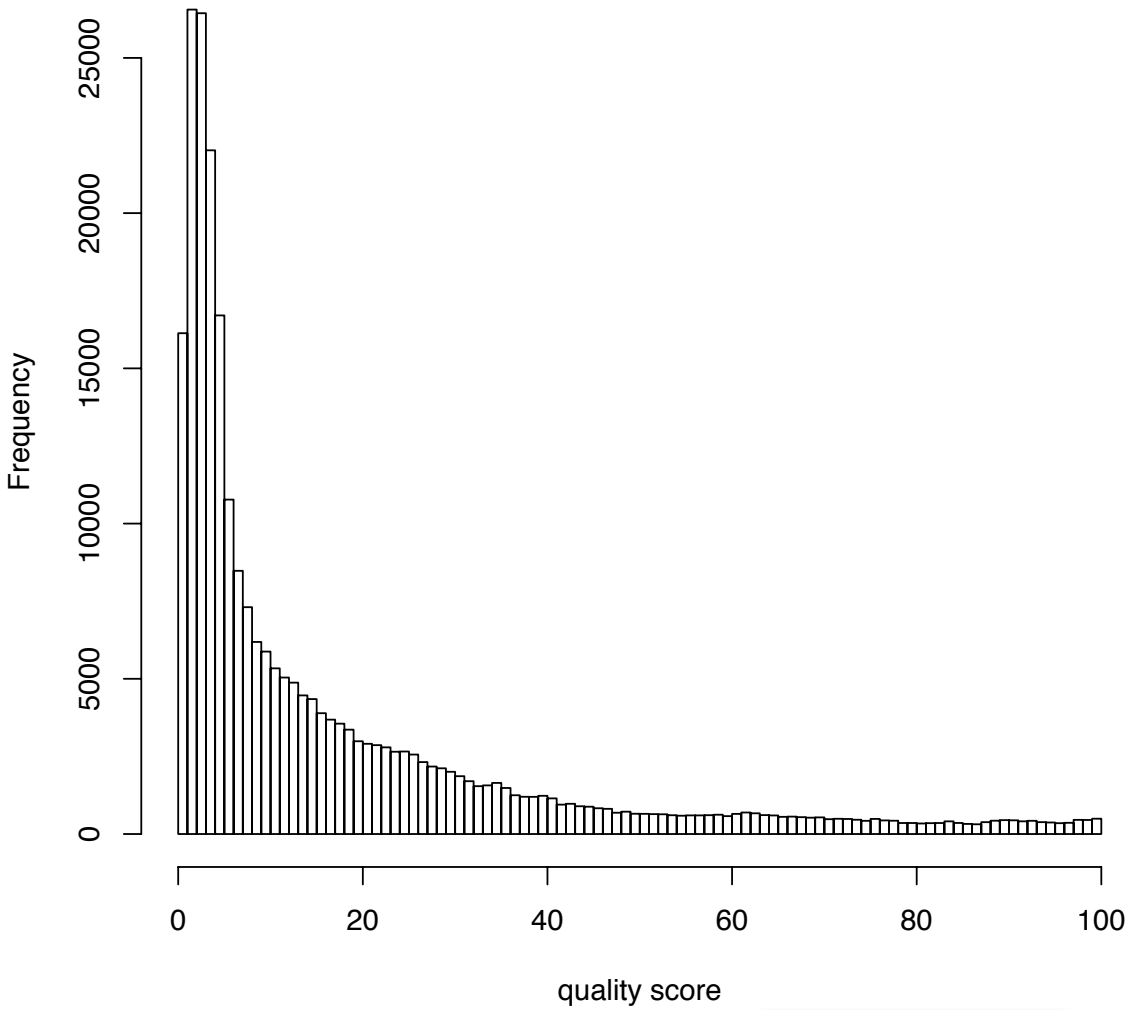


Scenarios

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

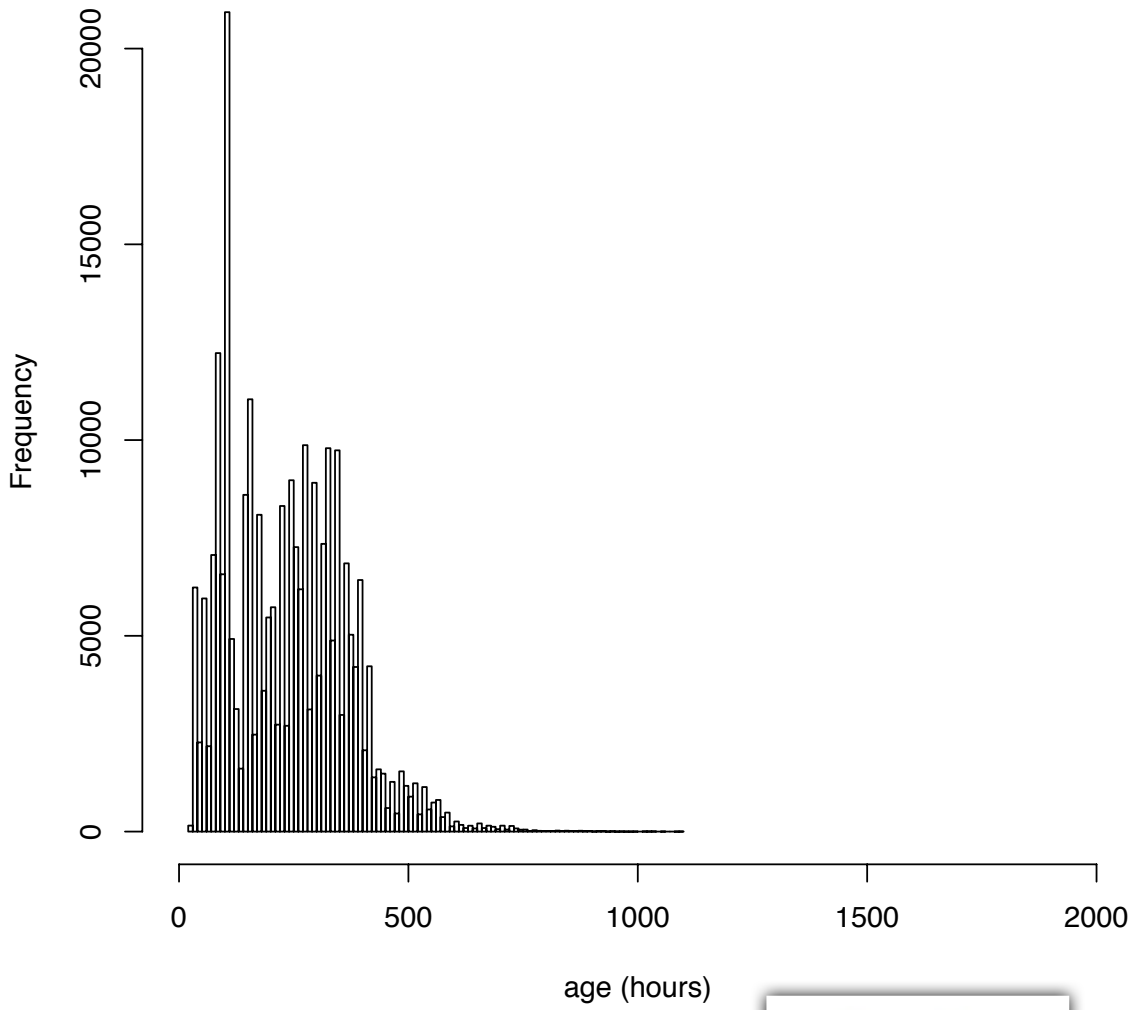
Scenario 1



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

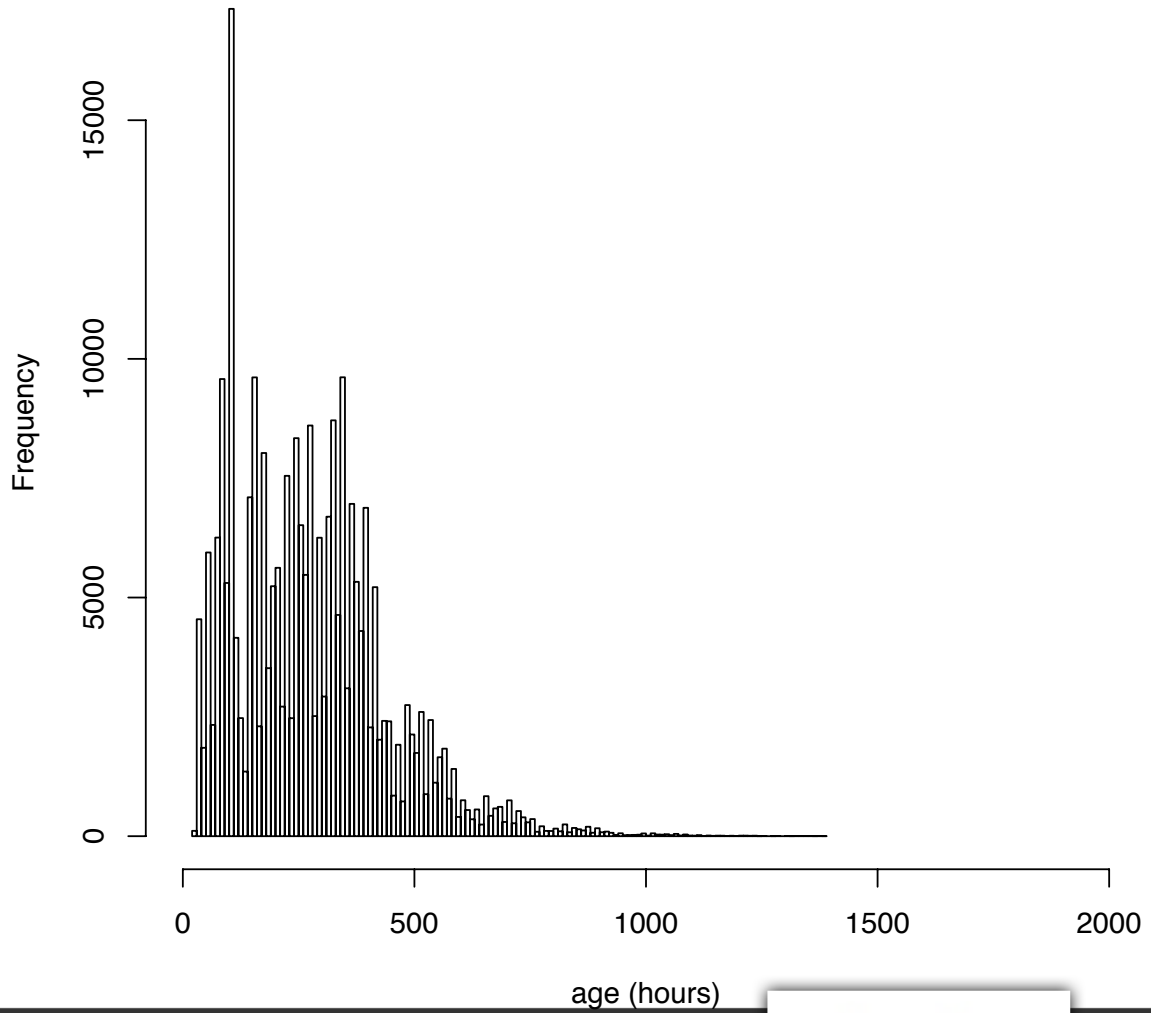
Scenario 2

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



Scenario 1

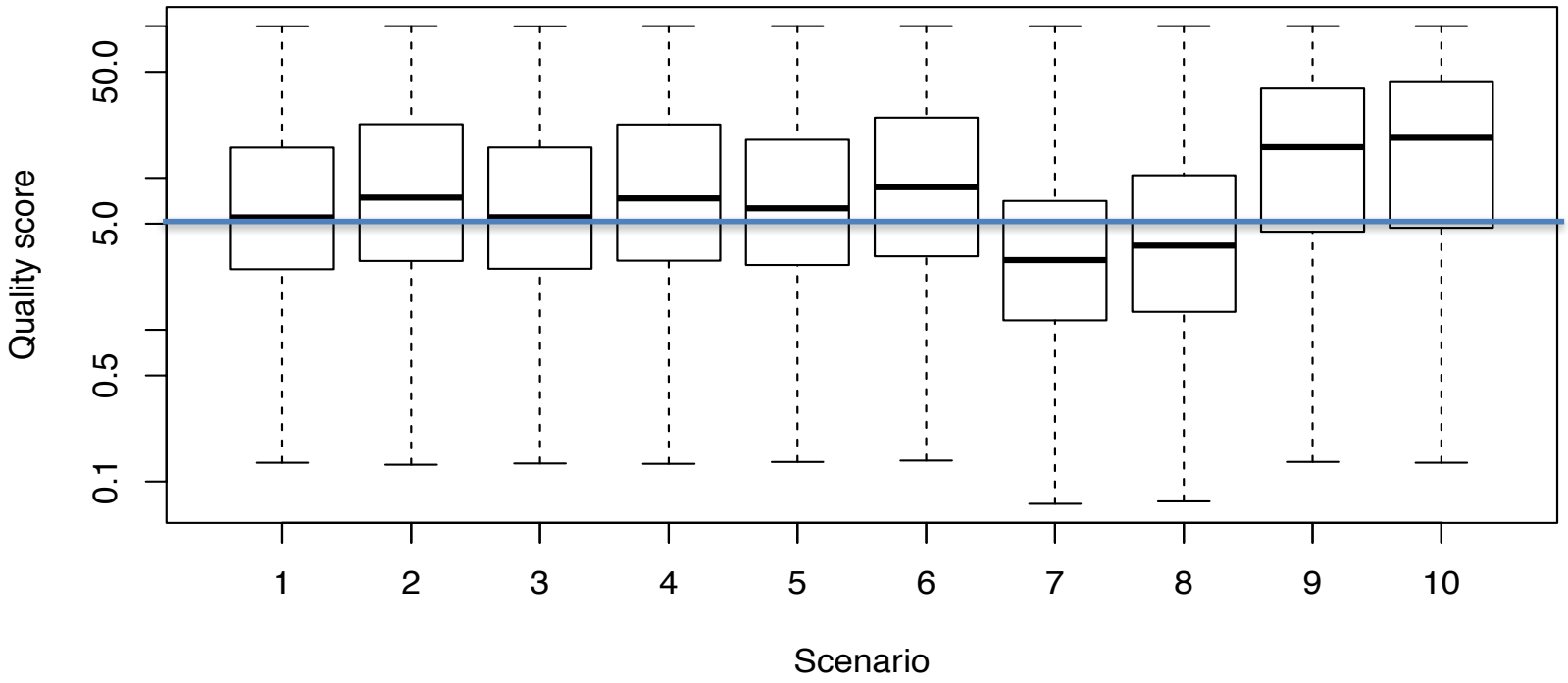
Scenarios
1 & 2 : Base
3 & 4 : Climate change
5 & 6 : Repacking
7 & 8 : Higher quality
9 & 10: Higher fuel costs



Scenario 2

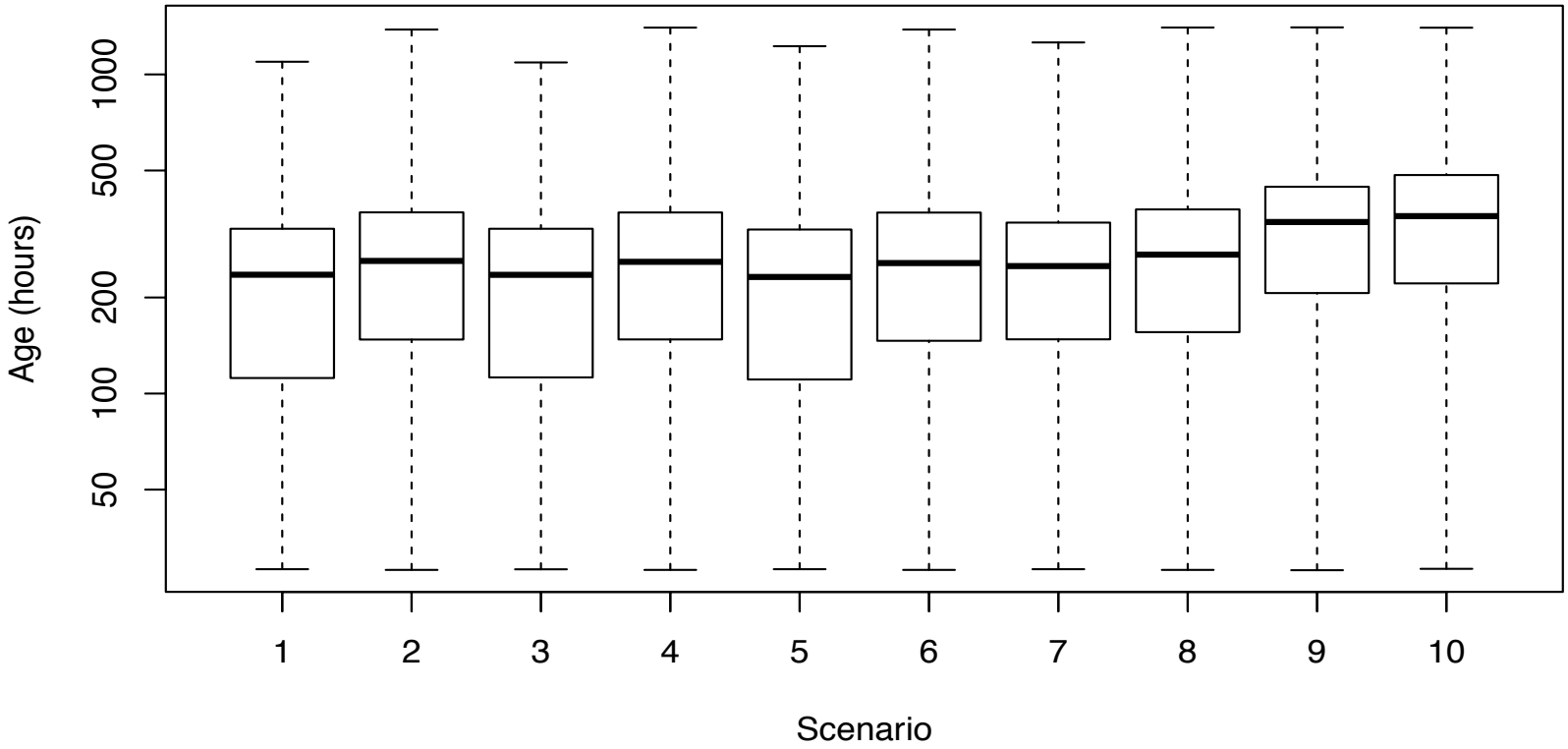
Quality at consumption

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



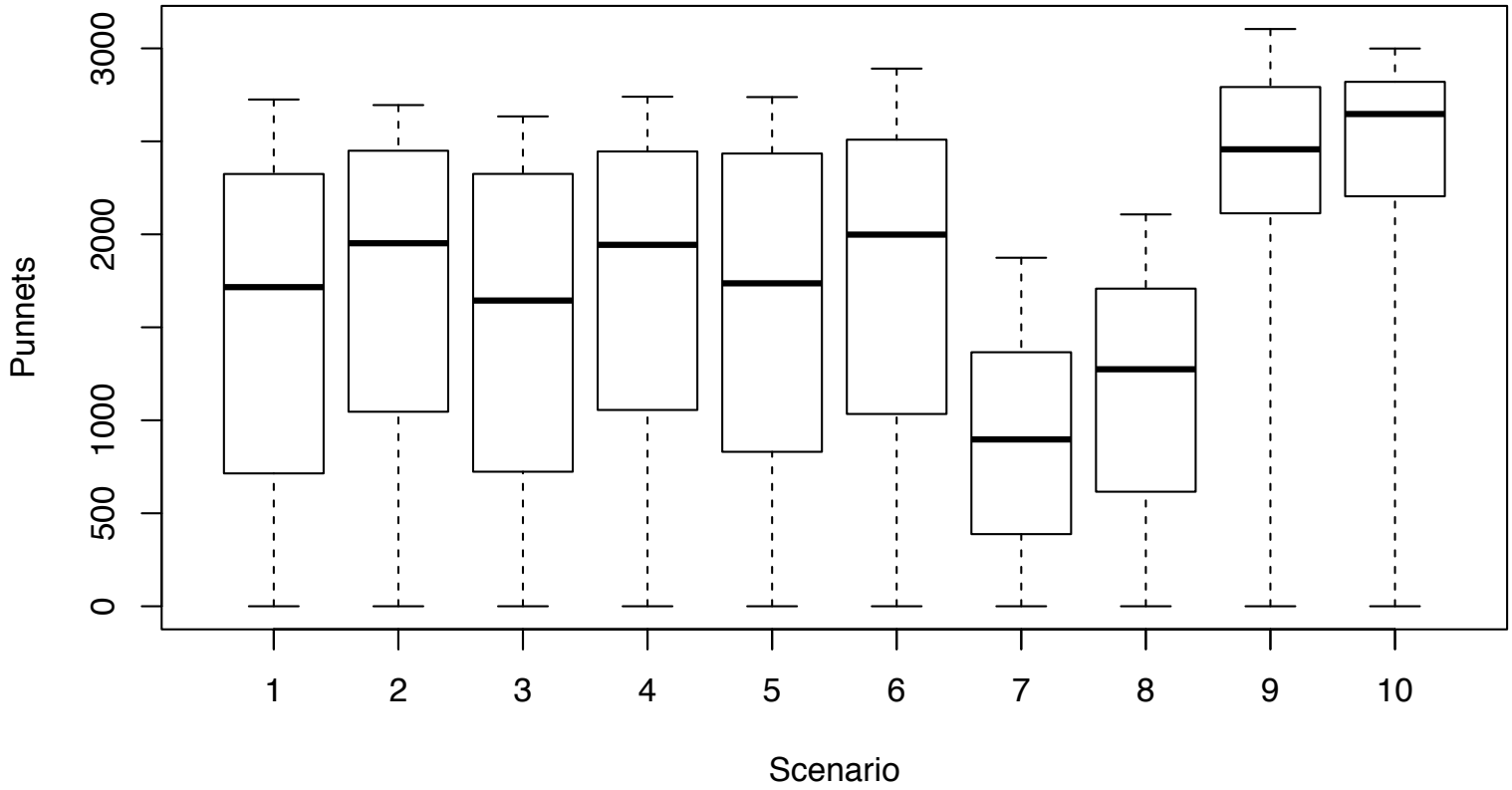
Age at consumption

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



Retailer waste

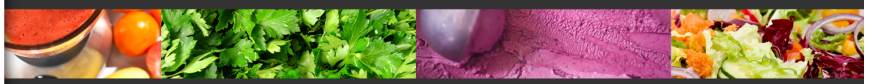
Scenarios
1 & 2 : Base
3 & 4 : Climate change
5 & 6 : Repacking
7 & 8 : Higher quality
9 & 10: Higher fuel costs



Discussion

RQ1. Does a dual sourcing inventory control policy, whilst reducing costs, **guarantee a sufficient quality** at consumption and reasonable waste?

- A **dual-index policy performs poorly** compared to a constant order policy.
- Note that, as shown in (Klosterhalfen et al., 2011) **none of these policies dominate the other** from a cost perspective.
- the **more constant inflow of fresh products** ensured by a **constant order policy** guarantees higher quality at consumption and reduces waste at retailers
- **both the policies perform poorly** with respect to the given acceptance criterion.

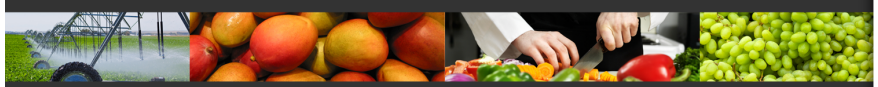



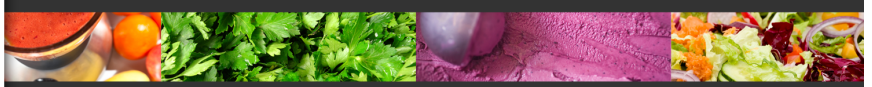
Discussion

RQ2. How **sensitive** is a dual sourcing policy to **variations of initial quality and temperatures** along the chain?

- 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.

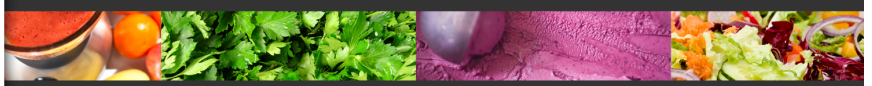




Discussion

RQ3. What is the **impact of fuel cost** variation on final product **quality** and on **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

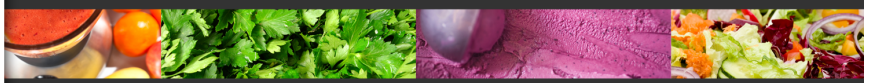
- Impact of **controlled atmosphere** in the warehouse is not taken into account.
  - Products are typically stored under **modified CO_2 concentrations** that tend to **reduce or even stop** mold growth.
  - Advanced model for strawberry quality include the effect of CO_2 concentration. In this sense, **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.

SEVENTH FRAMEWORK PROGRAMME

veg-i-trade (grant agreement no. 244994) is funded under the Seventh Framework Programme of the European Commission.

FP7 website: ***http://cordis.europa.eu/fp7***
veg-i-trade website: ***http://www.veg-i-trade.org***

A final remark…