Managing yield uncertainty in a hybrid manufacturing / remanufacturing inventory system

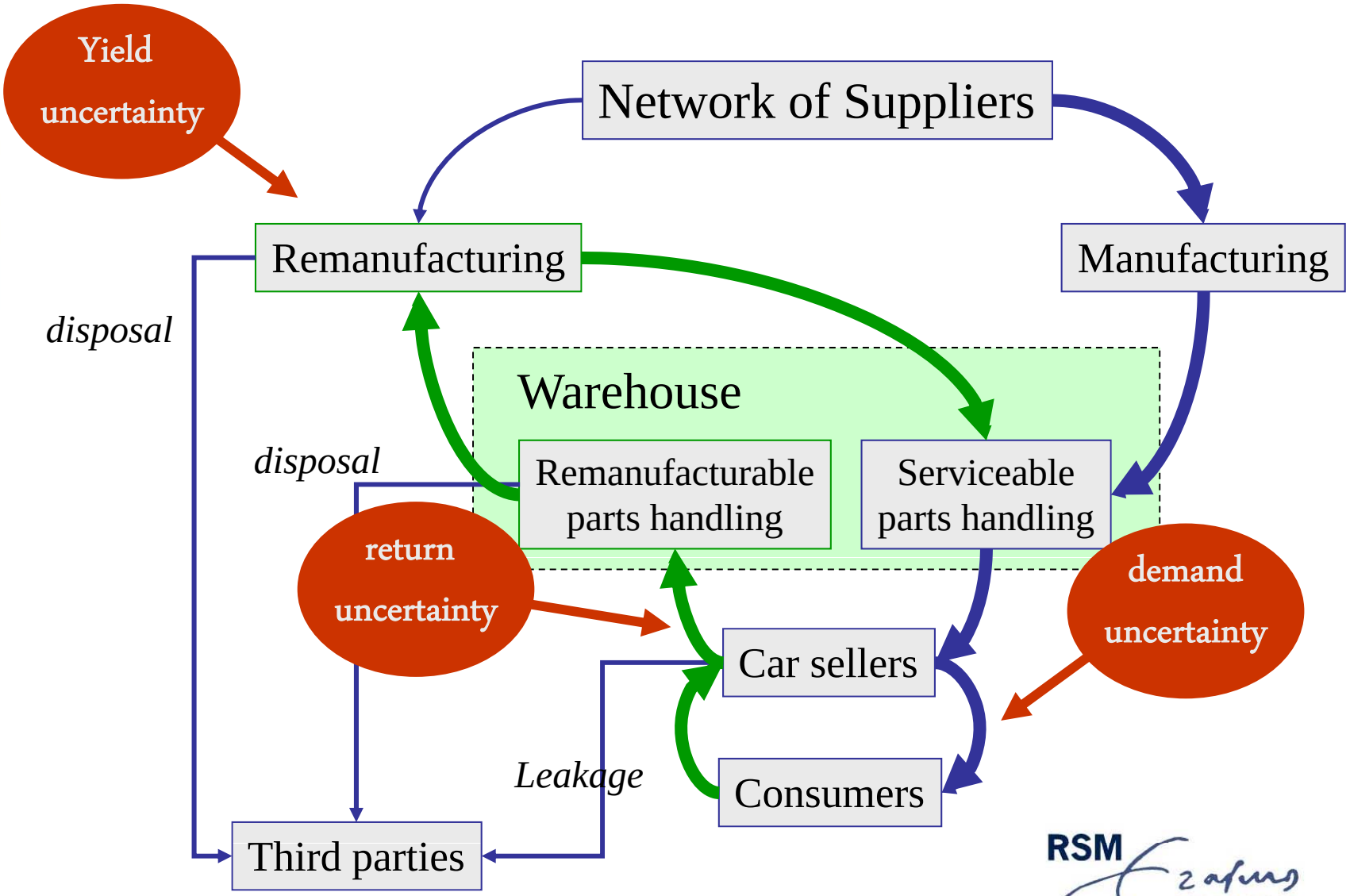
Erwin van der Laan
Rotterdam School of Management,
Erasmus University

Agenda

- Underlying case
- Modeling framework
- Heuristics for near-optimal inventory decisions
- Impact of yield uncertainty → numerical study
- Managerial implications

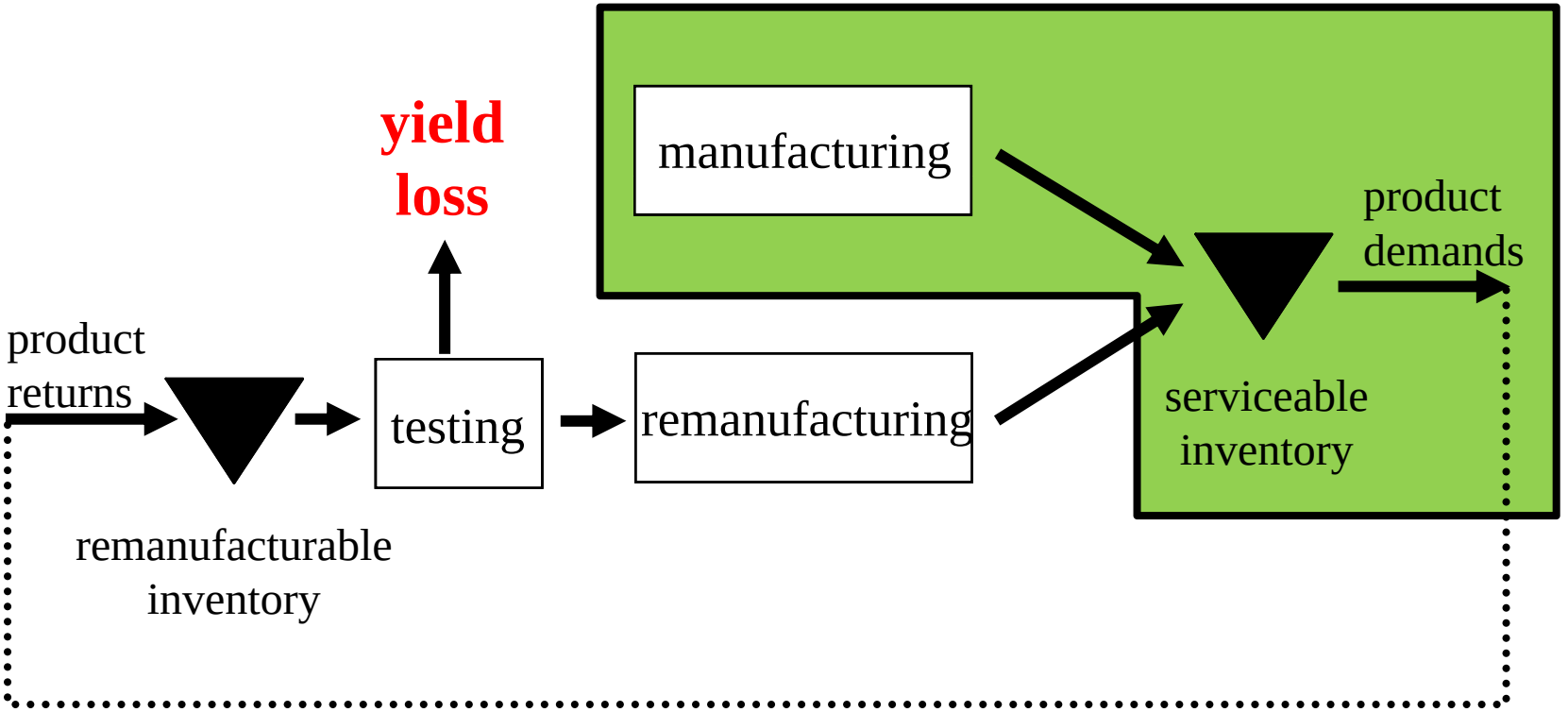
RSM Erasmus
ERASMUS UNIVERSITY

Joint manufacturing/remanufacturing of car parts



RSM Erasmus University

Framework for joint (re)manufacturing



(Near) optimal policies?

- **What structure do optimal policies have?**

  - Inderfurth ’97 → (L,M,U) – policy

  (discrete time; equal leadtimes; no fixed costs; no yield loss)

  - Fleischmann & Kuik ’02 → (*s*,*S*) manufacturing Policy;

  (instantaneous remanufacturing, no yield loss)

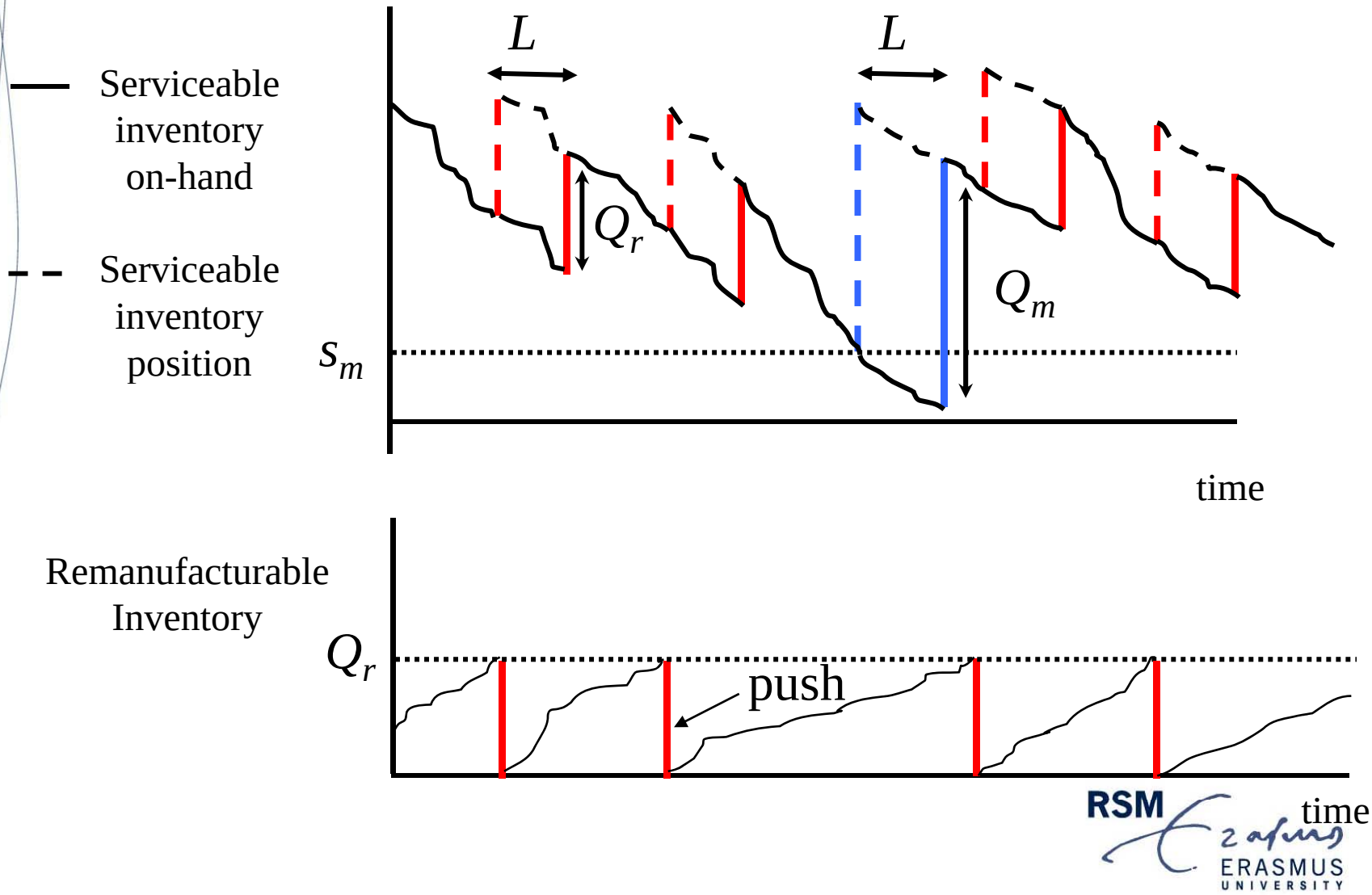
- **What are ‘near optimal’ control policies?**

  - Van der Laan et al. ’99 → push & pull remanufacturing

(continuous review, fixed costs, non-zero leadtimes)

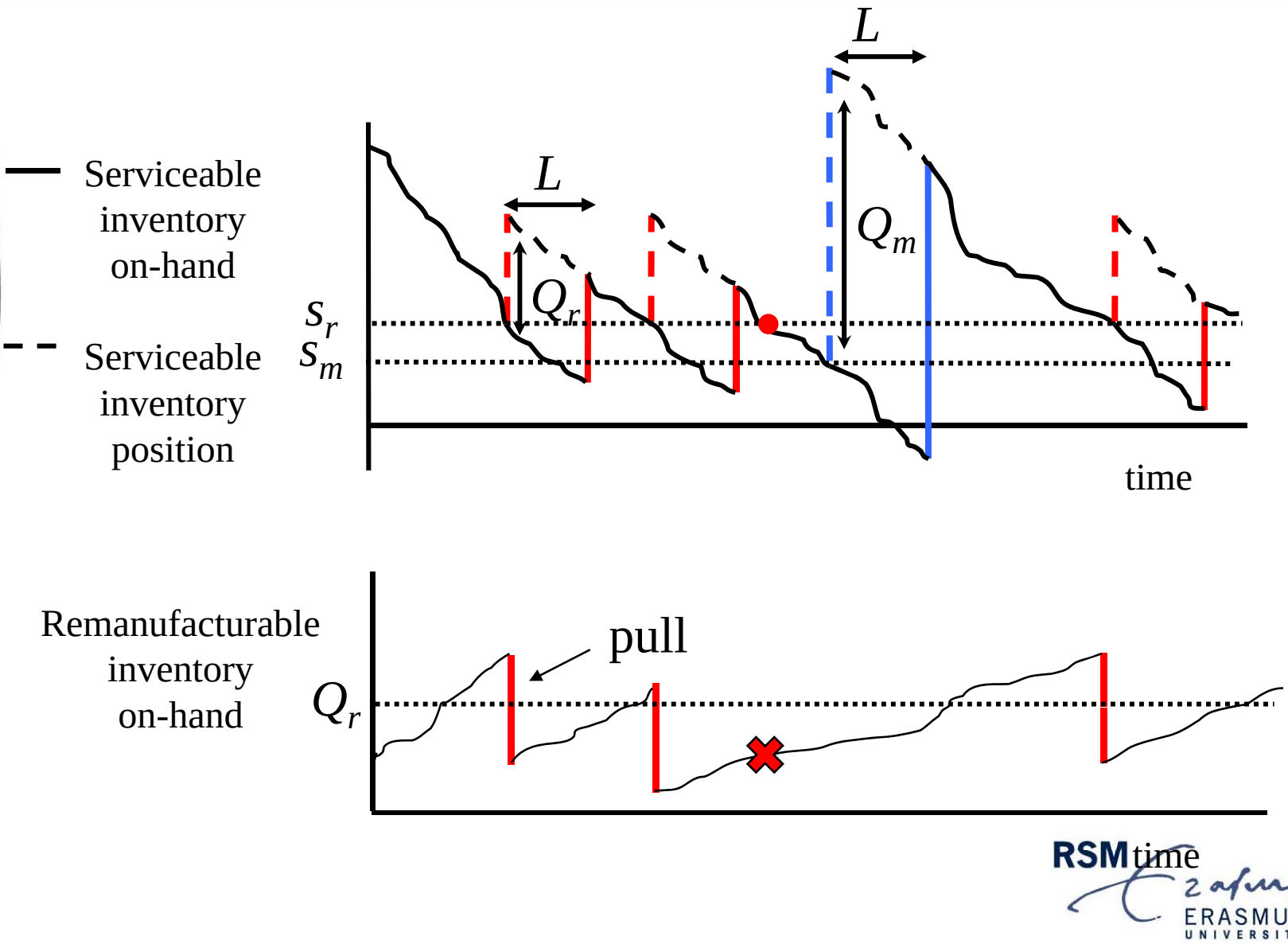
RSM Erasmus
ERASMUS UNIVERSITY

Push remanufacturing (no yield loss)



RSM Erasmus University

Pull remanufacturing (no yield loss)



RSM time

ERASMUS UNIVERSITY

Three scenarios w.r.t. testing

1. **Instantaneous testing**

   Yield uncertainty is resolved as soon as the remanufacturing order is placed**.**

2. **Reactive updating**

   - Testing times are stochastic

   - Inventory position is updated **after** testing.

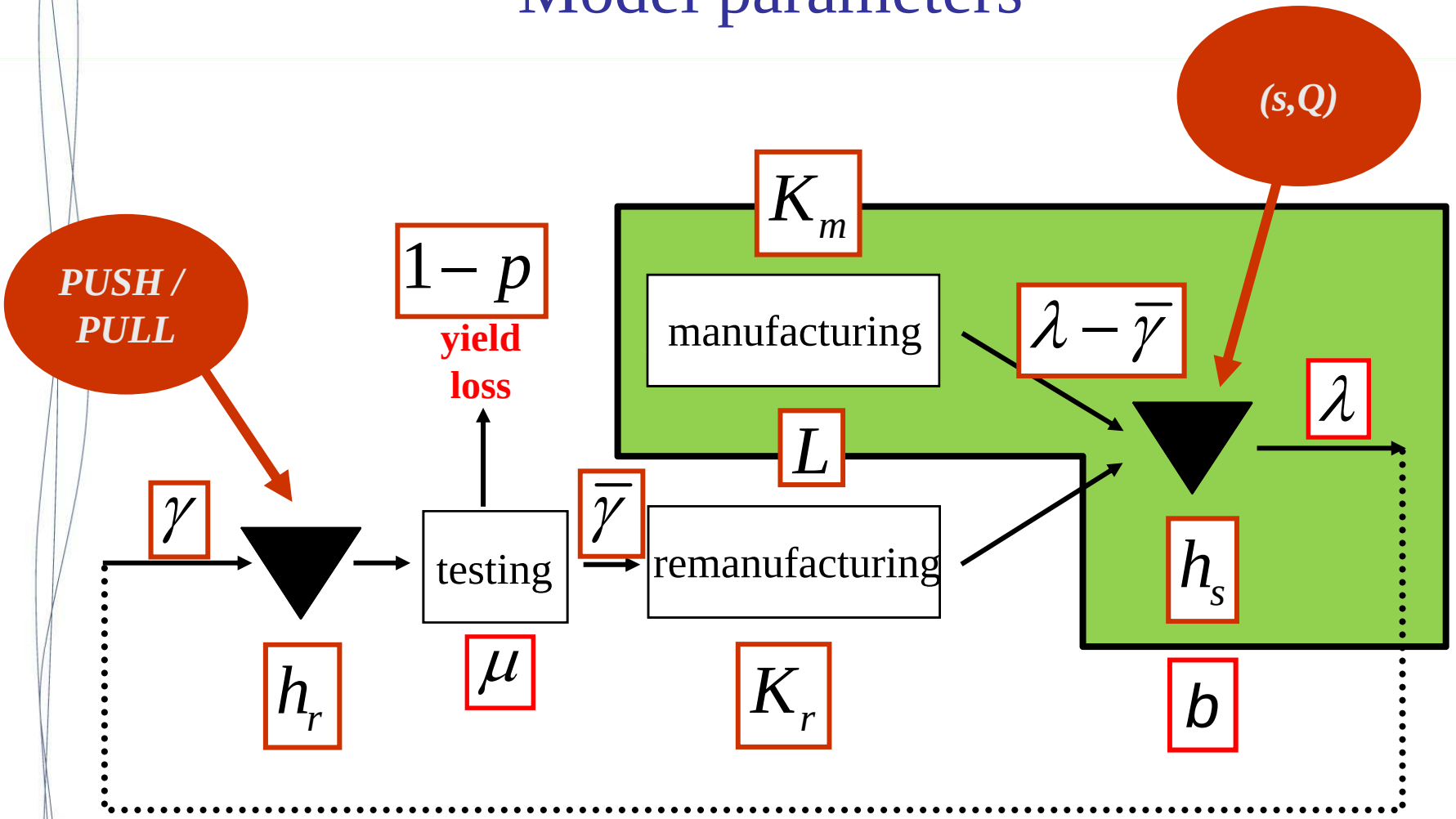
3. **Proactive updating**

   - Testing times are stochastic.

   - Inventory position is updated **before** and **after** testing.

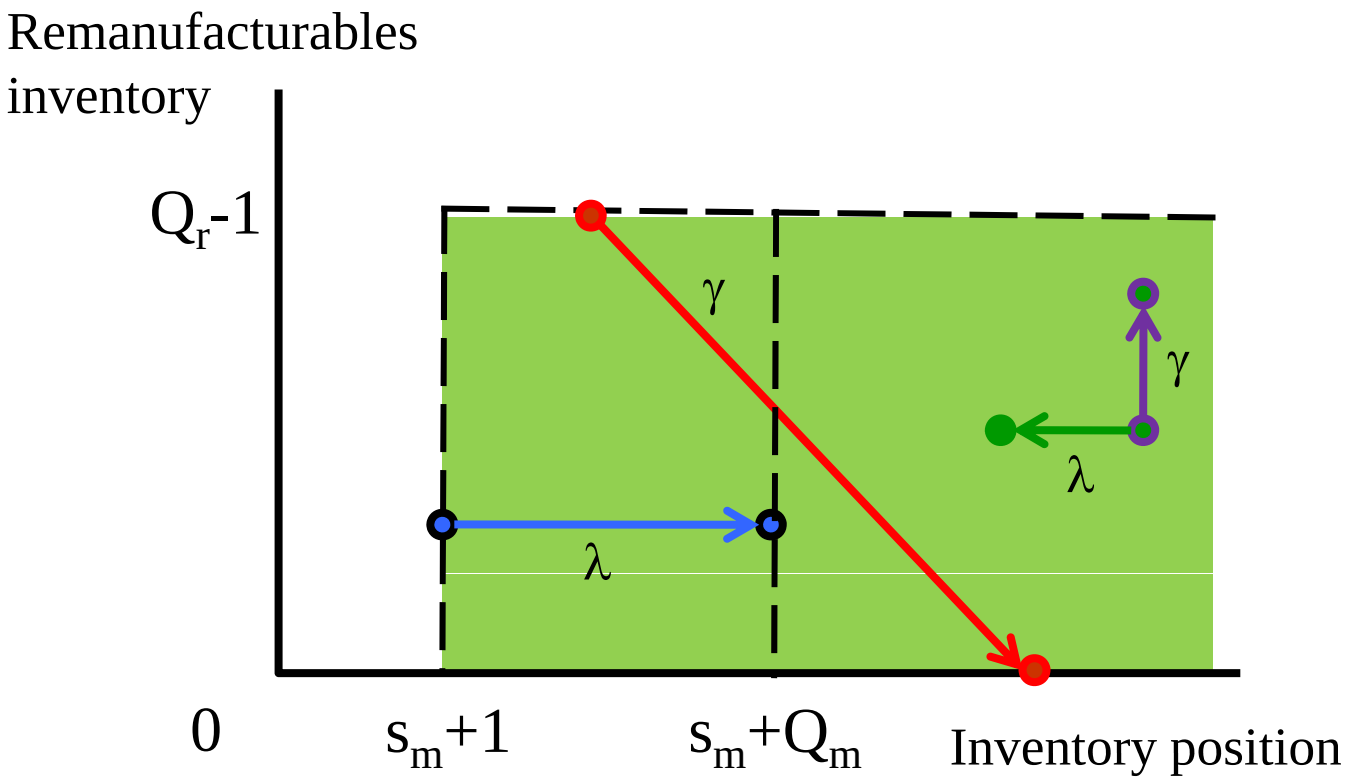
RSM Erasmus ERASMUS UNIVERSITY

Model parameters



RSM Erasmus University

PUSH with instantaneous testing
→ Markov chain modeling of inventory position



$$N(t)=IP(t-L) - D(t-L, t)$$

RSM Erasmus University

Heuristic order quantities

PUSH	$Q_{man} = \sqrt{\frac{2(\lambda + \bar{\gamma})K_m}{h_s}}$	$Q_{rem} = \sqrt{\frac{2\gamma K_r}{h_r + (p\bar{\gamma}/\lambda)h_s}}$
PULL	$Q_{man} = \sqrt{\frac{2(\lambda - \bar{\gamma})K_m}{(\gamma/\lambda)h_r + (1 - \bar{\gamma}/\lambda)h_s}}$	

Source: ***Corbacioglu & Van der Laan (2009),*** *"Heuristics for Push and Pull remanufacturing with yield uncertainty", proceedings of the 2009 EUROMA conference, Gothenburg, Sweden.*

RSM Erasmus ERASMUS UNIVERSITY

Heuristic reorder levels

PUSH

$$s_m = F^{-1}\left(1-\left(\frac{h_s}{b}\right)\left(\frac{Q_m}{\lambda+\bar{\gamma}}\right)\right)$$

PULL

$$s_m = F^{-1}\left(1-\left(\frac{h_s}{b}\right)\left(\frac{Q_m}{\lambda}\right)\right)$$

$$s_r = F^{-1}\left(1-\left(\frac{h_s}{b}\right)\left(\frac{pQ_r}{\lambda}\right)\right)$$

With F^{-1} the inverse cumulative distribution of demand during leadtime

Source: ***Corbacioglu & Van der Laan (2009),*** *"Heuristics for Push and Pull remanufacturing with yield uncertainty", proceedings of the 2009 EUROMA conference, Gothenburg, Sweden.*

RSM Erasmus ERASMUS UNIVERSITY

Full factorial experimental design

Demand rate (λ)	10 (Poisson process)
Return rate (γ)	5, 7, 9 (Poisson process)
Test rate (μ)	2, 4, 8 (Exponential)
Yield probability (p)	0.5, 0.7, 0.9
Lead time (L)	2
Serviceables holding cost (h_s)	1
Remanufacturables holding cost (h_r)	0, 0.5, 1.0
Backorder cost (b)	100
Fixed manufact. cost (K_m)	10
Fixed remanufact. cost (K_r)	10

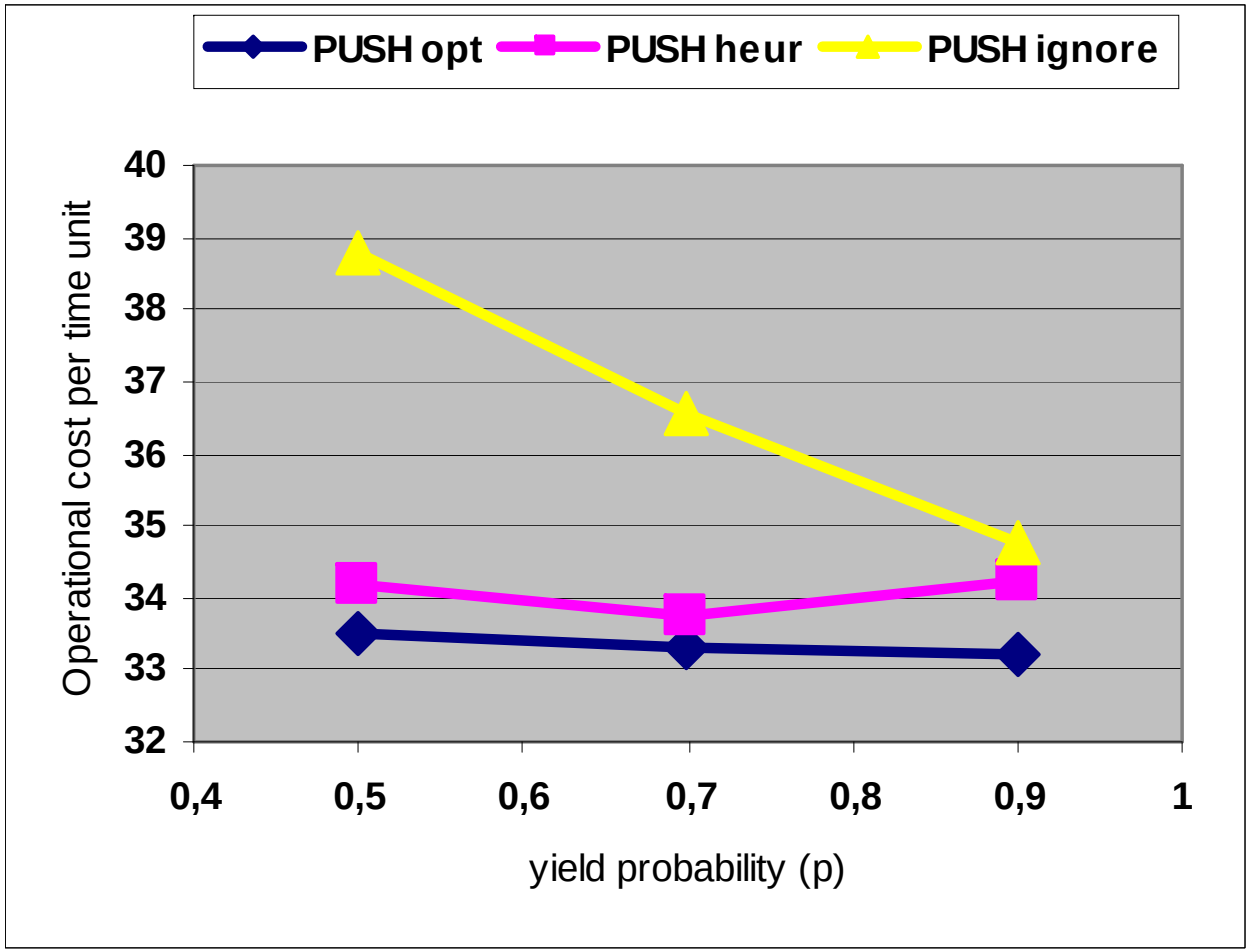
All 81 scenarios are evaluated based on exact costs.

RSM Erasmus
ERASMUS UNIVERSITY

Instantaneous testing

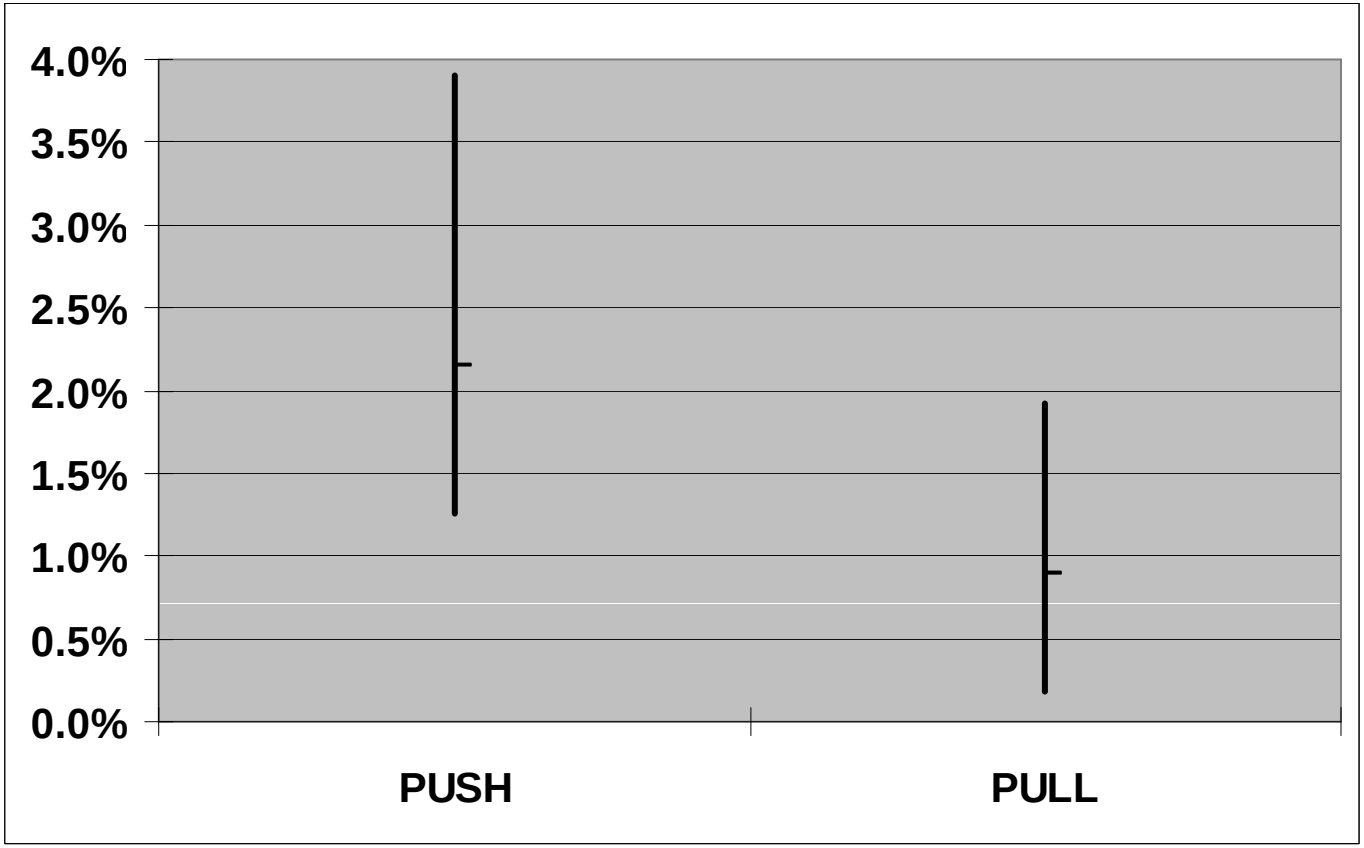
RSM Erasmus
ERASMUS UNIVERSITY

Effects of yield loss: operational cost



RSM Erasmus ERASMUS UNIVERSITY

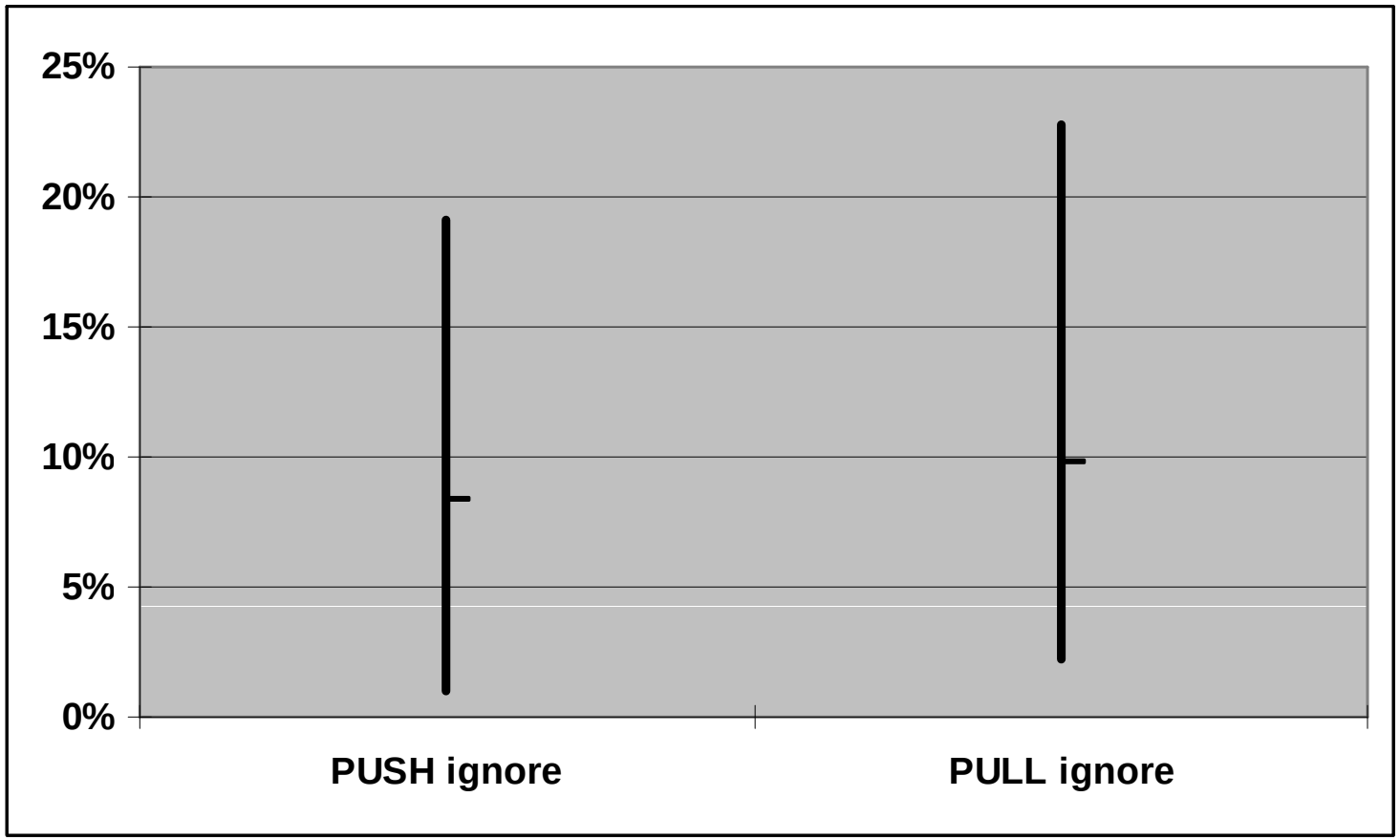
Cost performance: heuristics



Based on all 81 scenarios

RSM Erasmus University

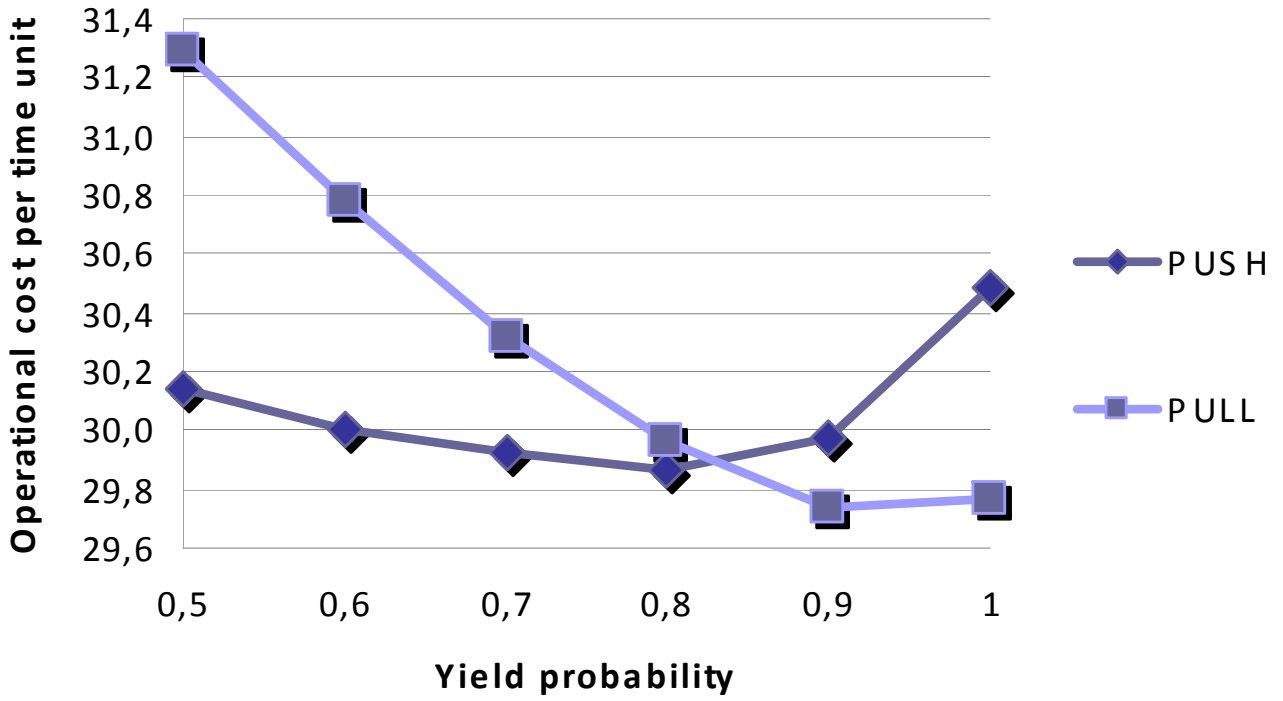
Cost performance: ignoring yield



Based on all 81 scenarios

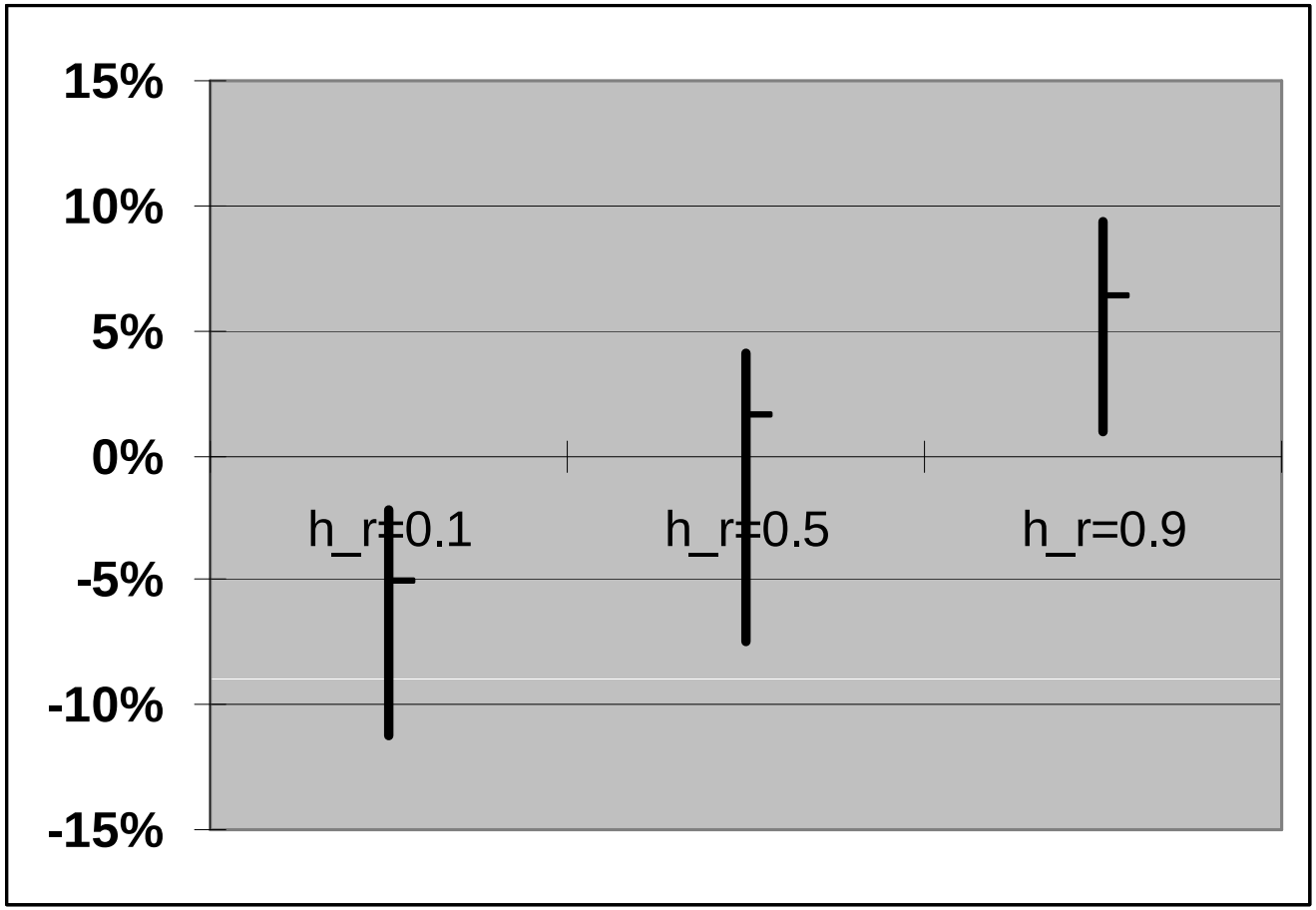
RSM Erasmus
ERASMUS UNIVERSITY

PUSH versus PULL



RSM Erasmus ERASMUS UNIVERSITY

PUSH versus PULL



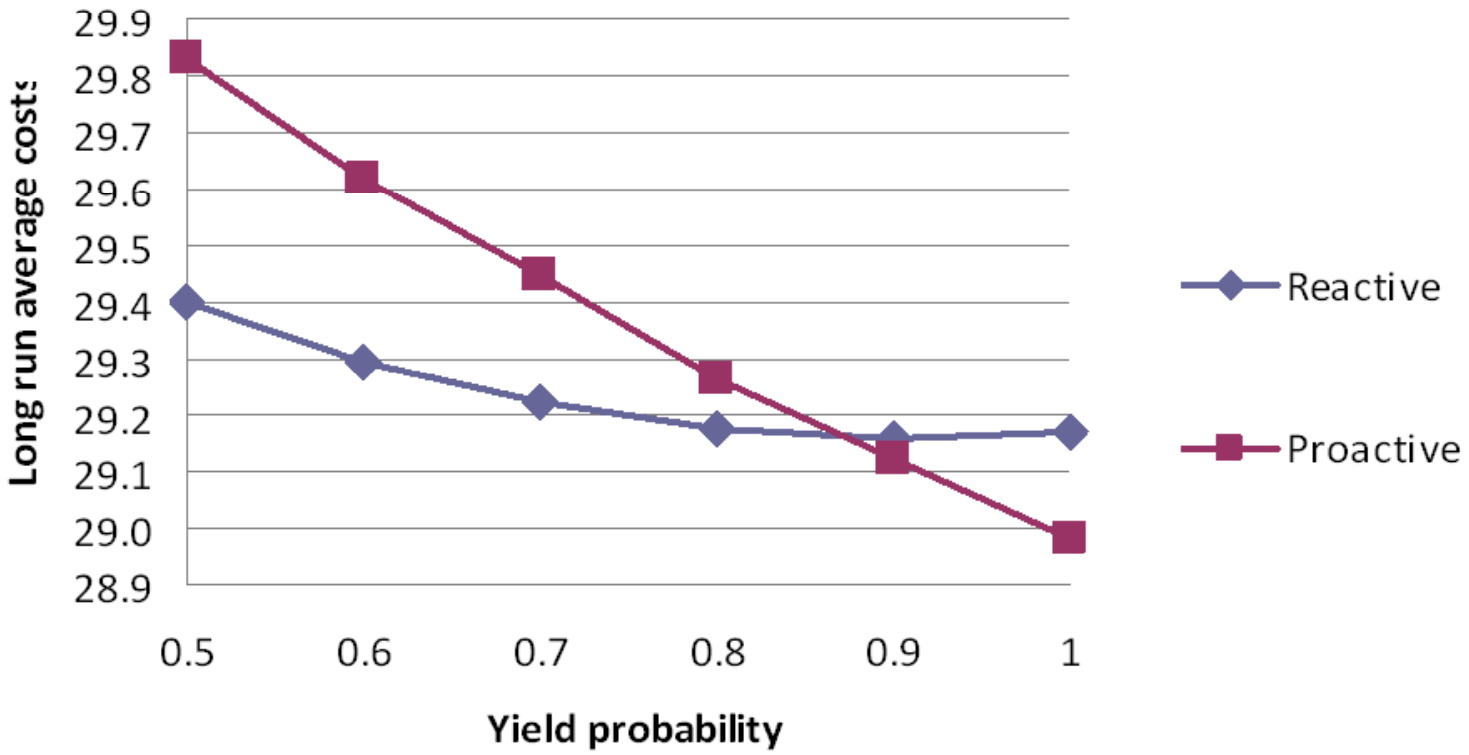
Based on all 243 scenarios

RSM Erasmus
ERASMUS UNIVERSITY

Reactive vs Proactive updating

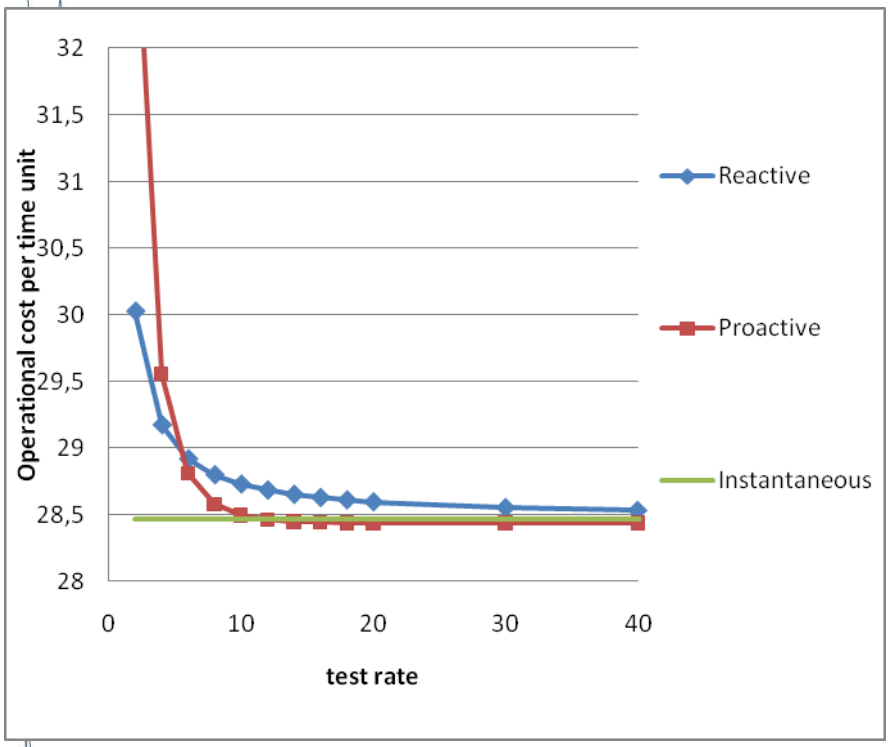
RSM Erasmus
ERASMUS UNIVERSITY

Reactive vs proactive updating (PUSH)

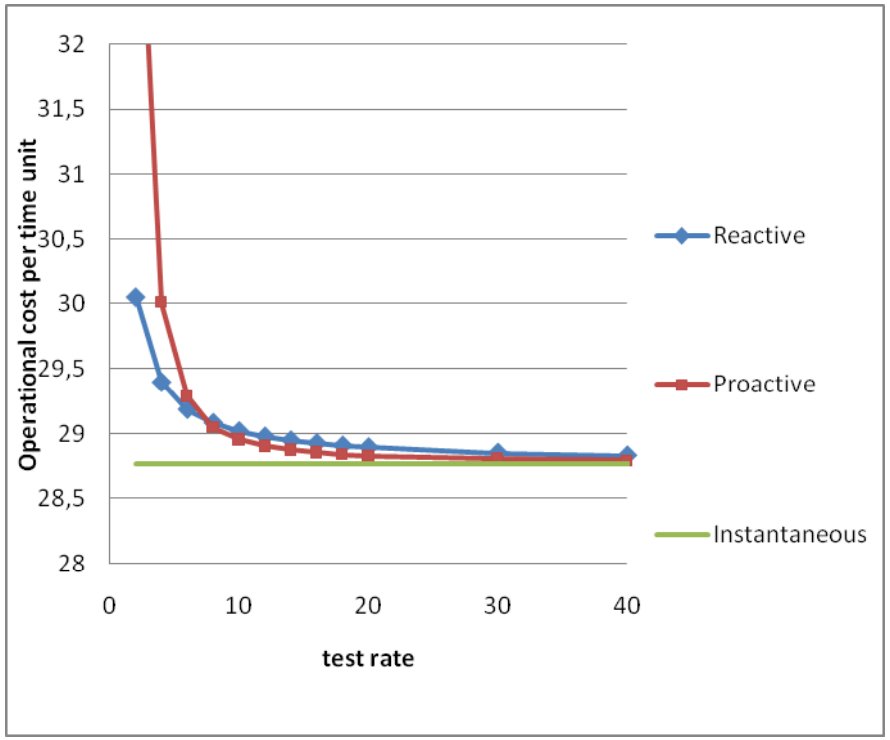


RSM Erasmus University

The effect of the testing rate (PUSH)



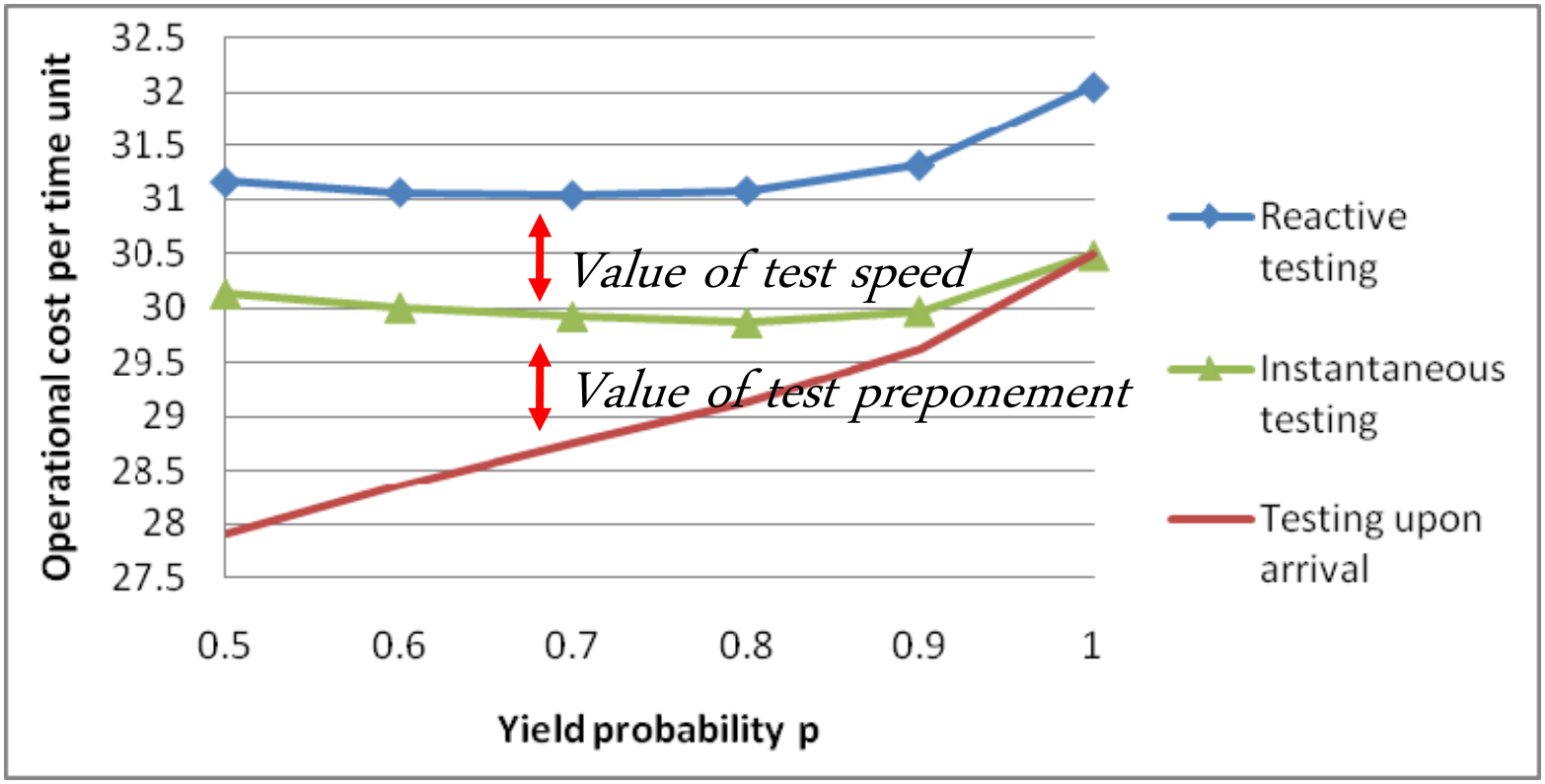
p=1.0



p=0.5

RSM Erasmus University

Value of early testing (PUSH)



RSM Erasmus University

Managerial implications

•Yield uncertainty has significant impact on optimal decisions and operational costs

→ Ignoring the yield is not an option

•PUSH vs PULL → mainly depends on holding cost ratio (h_r / h_s)

•Reactive updating is generally preferable

•Early testing pays off as long as

- there is no substantial additional cost
- There is low risk of misidentification

RSM Erasmus University

Thank you!

elaan@rsm.nl

RSM Erasmus
ERASMUS UNIVERSITY