Delivery Lead Time and Flexible Capacity Setting for Repair Shops with Homogenous Customers

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Where innovation starts

OUTLINE

- Introduction & Motivation
- Literature Review
- Model & Assumptions
  - Ideal Case: Centralized Decision Problem
  - Decomposed Decision Problem
- Setting the Scene for Flexibility

INTRODUCTION & MOTIVATION

- **After Sales Services become more important (Cohen et. al, HBR 2006)**
- **For Capital Goods → maintenance**
  - **Preventive**
  - **Corrective**
- **Capital Goods which are commoditized to some extent:**

Forklifts

Trucks

Construction Eq.

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INTRODUCTION & MOTIVATION

- **Commoditized Capital Goods Environment**
  - **Numerous users**
  - **Rental suppliers available**

- **Different strategies to minimize downtime costs**
  - **Hiring a substitute machine during repair?**

One of the biggest Forklift Supplier & Service Provider in the Benelux Area at Rijswijk

Serves numerous customers (Hypothetically at)

Repair Shop & Rental Store are nearby

Upon a failure, failed forklift is sent to the repair shop and a substitute forklift from the rental store can be hired for a fixed amount of time.

INTRODUCTION & MOTIVATION

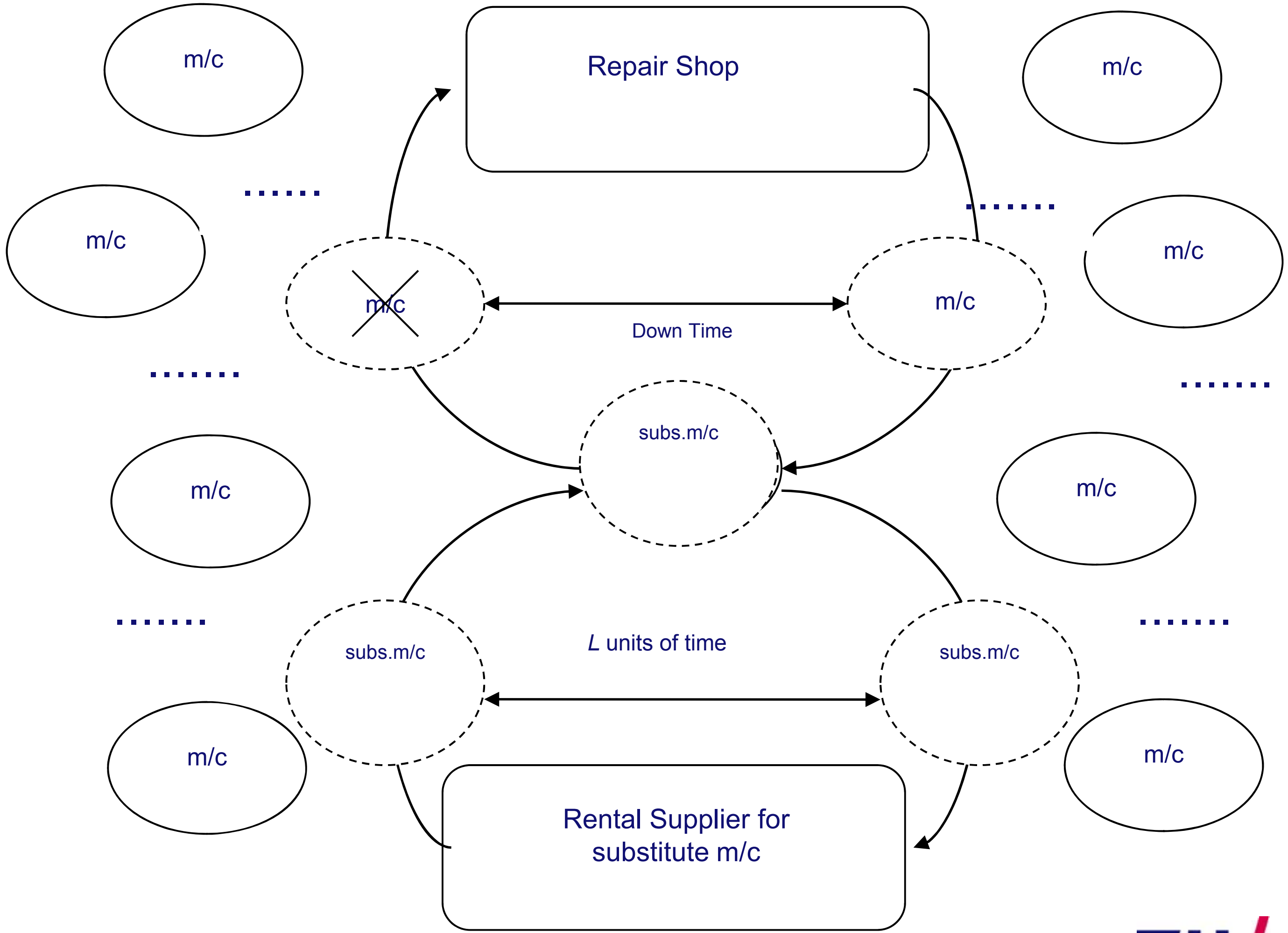
RESEARCH QUESTIONS

1. **How should the repair shop capacity & hiring duration decisions be given?**
   a) **Central Decision Problem (As a Benchmark)**
   b) **Decomposed Decision Problem (when Repair Shop uses C+ pricing)**
      − Role of Lead Time Performance Requirements
2. **How can one make use of capacity flexibility in this environment?**

LITERATURE REVIEW

- **Surveys on Maintenance:**
  - Pierskalla and Voelker (1976), Sherif and Smith (1982),Cho&Parlar (1990), Dekker(1996), Wang (2002)
- **Capacity Management in Machine Interference Problem:**
  - Crabill(1974), Winston(1977,1978), Allbright (1980)
- **Capacity Management in Repairable-Item Inventory models:**
  - Gross et al. (1983,1987), Scudder (1985), De Haas (1995)
- **Lead Time Management**
  - Duenyas and Hopp (1995), Spearman and Zhang (1999), Elmaghraby and Keskinocak (2004)

MODEL & ASSUMPTIONS



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MODEL & ASSUMPTIONS

Instantaneous Shipment from/to the Repair shop & the Rental Store

Failures ~Poisson (λ) (w.l.o.g $\lambda = 1$ failure per week.)

Each failure requires a random service time at the repair shop

Repair Shop: Aggregately Planned as a single Server Queue

Capacity of the Repair shop: Service Rate (Can be interpreted as the weekly working hours)

We pay *h$* during *L* unit of time, which is non-refundable

If Down-time>*L* → we loose *B$* per unit time until the repaired machine is returned (*B*>*h*)

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MODEL & ASSUMPTIONS

Repair Shop's Total Costs per unit time

$$RSTC(\mu) \quad = K + c_p\, \mu.$$

***K*: Fixed Component (Transportation & other sunk costs)**

c_p : Normalized wage factor for the repair shop

Repair Shop: cost plus (C+) strategy for determining price per repair

$$p(\mu) = RSTC(\mu)/\lambda + \alpha\,.$$

μ →Sojourn time distribution (density) function ,$F_\mu(.)$, ($f_\mu(.)$)

Given μ and L, total cost during downtime cycle $TCDT(\mu, L)$

$(B > h)$

$$TCDT(\mu, L) = p(\mu) + hL + B\int_{x=L}^{\infty}(x-L)f_\mu(x)\,dx$$

MODEL & ASSUMPTIONS

CENTRAL DECISION MAKING:

Assumptions:

A central agent tries to minimize *TCDT (μ, L)* knowing all relevant information (*K*, c_p, *h*, *B*, *λ*, *α*, $F_\mu(.)$, $f_\mu(.)$)

(1) $$\min_{\mu,L} TCDT(\mu, L)$$

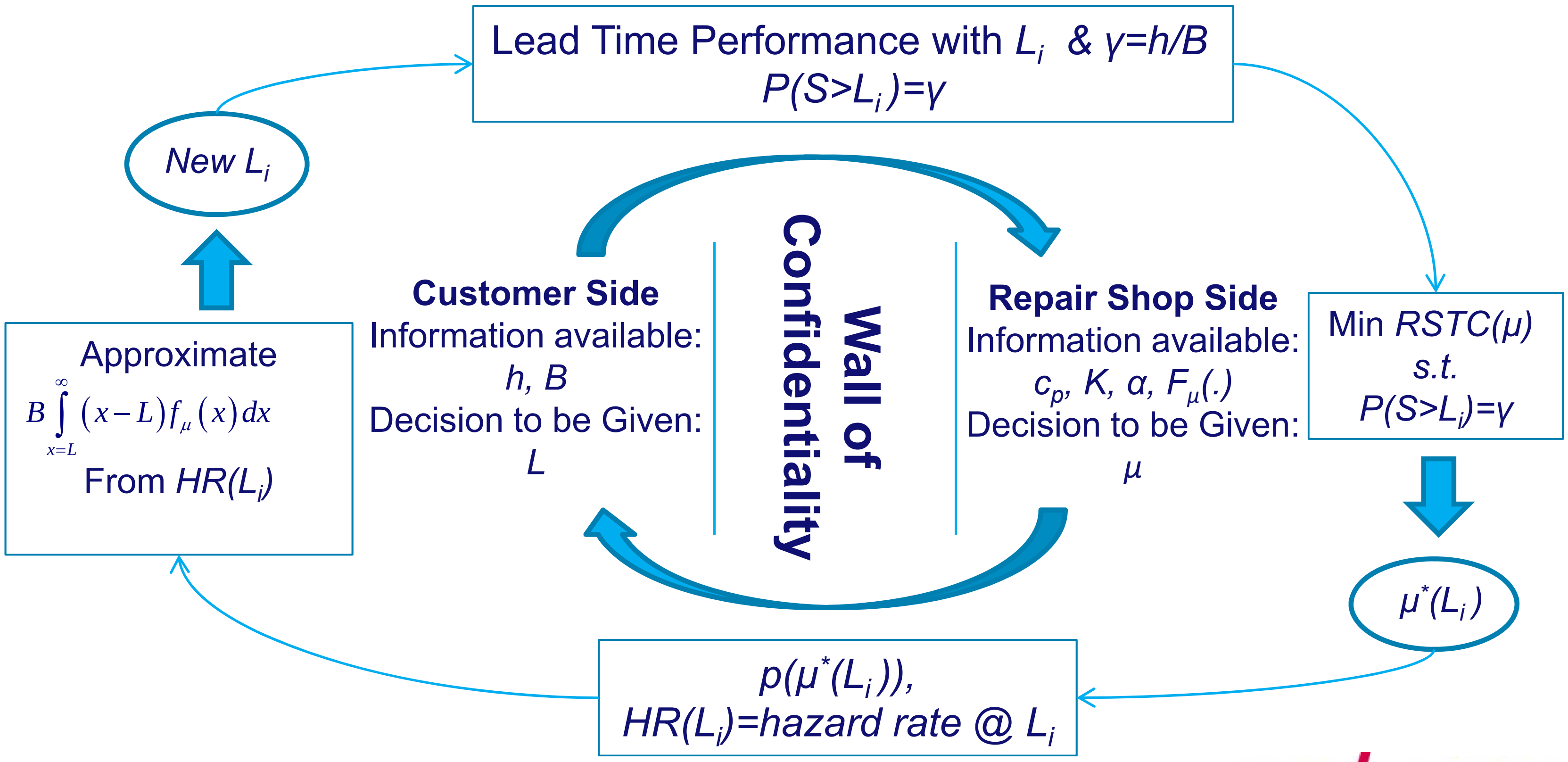
Special Case: Jointly Convex when *M/M/1*→F_μ~Exponential(*μ*-*λ*)

$$\mu^* = \lambda + \sqrt{\frac{\lambda h\left(1-\ln\left(\frac{h}{B}\right)\right)}{c_p}}$$

$$L^* = \frac{-\ln(\frac{h}{B})}{\sqrt{\frac{\lambda h\left(1-\ln\left(\frac{h}{B}\right)\right)}{c_p}}}$$

MODEL & ASSUMPTIONS

DECOMPOSED DECISION MAKING:

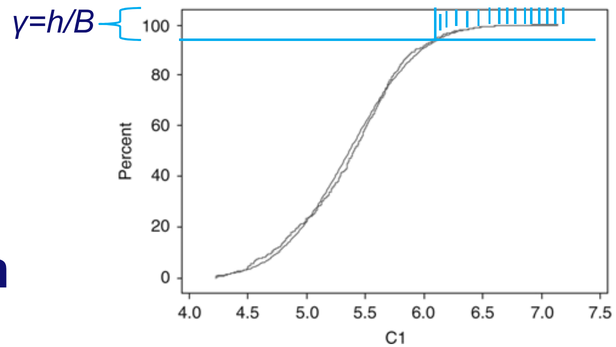


MODEL & ASSUMPTIONS

DECOMPOSED DECISION MAKING:

Approximation of $B\int_{x=L}^{\infty}(x-L)f_{\mu}(x)\,dx$ **is trivial for GI/M/1 systems.**

For general service times, → exponential tail asymptotic for the sojourn times of single server queues (Glynn and Whitt (1994), Abate et al(1995)).



Lead Time Performance Constraint

→ Smaller Feasible Region

→ *TCDT(L)* is a single variable function

Special Case: For *M/M/1, L^* satisfies an EOQ-like formula*

e.g. $aL^* + b/L^* = 0$

Same optimal L^* as the central decision problem

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Research Question 2
Setting the Scene for Capacity Flexibility

Hire Immediately-Send Periodically Policy

- **Each failed machine is sent to the repair shop only in equidistant points in time. (Period of length *D*)**
- **However a substitute machine is hired immediately.**
- **Hired during (time until next period + *L*)**
- **Time until next period ~ Uniform(*0,D*)**
- **Repair Shop → $D^{[X]}/M/1, X \sim$ Poisson(λD) (Buyukkaramikli et al. (2009))**

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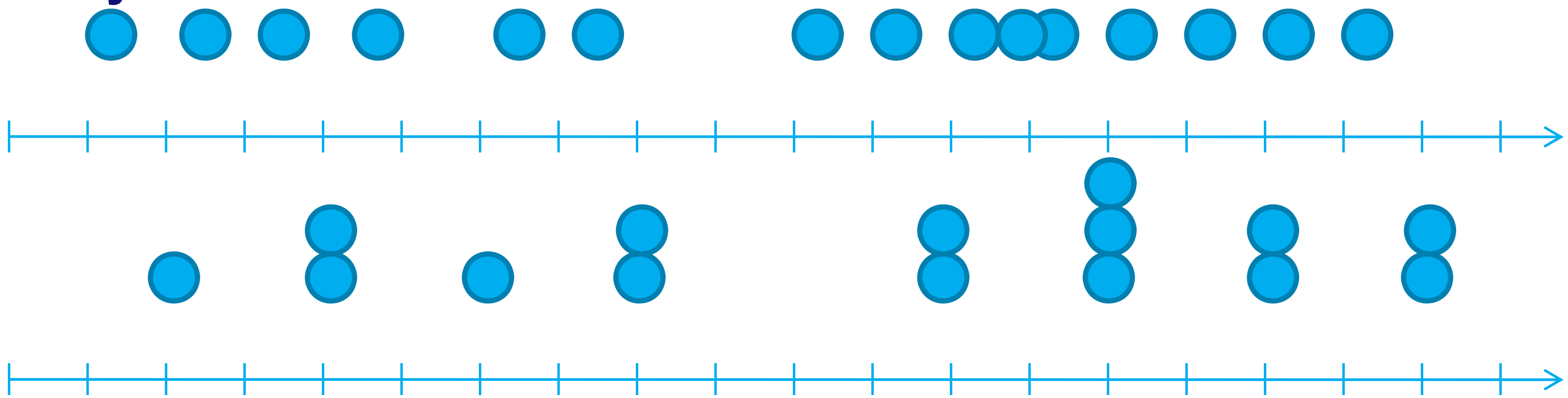
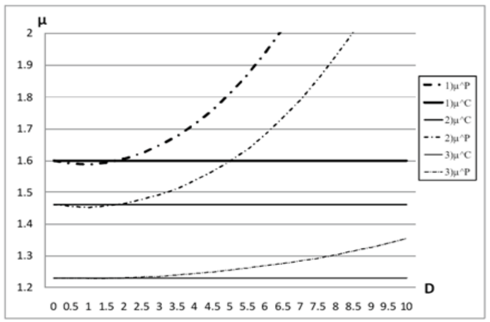
Research Question 2
Setting the Scene for Capacity Flexibility

Negative Effects

- **Additional Hiring of the substitute machine until the next period (*hD*/2)**
- **Burstiness in the arrival pattern because of sending failed machines periodically .**





We will analyze D<5

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Setting the Scene for Capacity Flexibility

Recall that *RSTC(μ)* = *K* + c_p *μ*

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Positive Effects

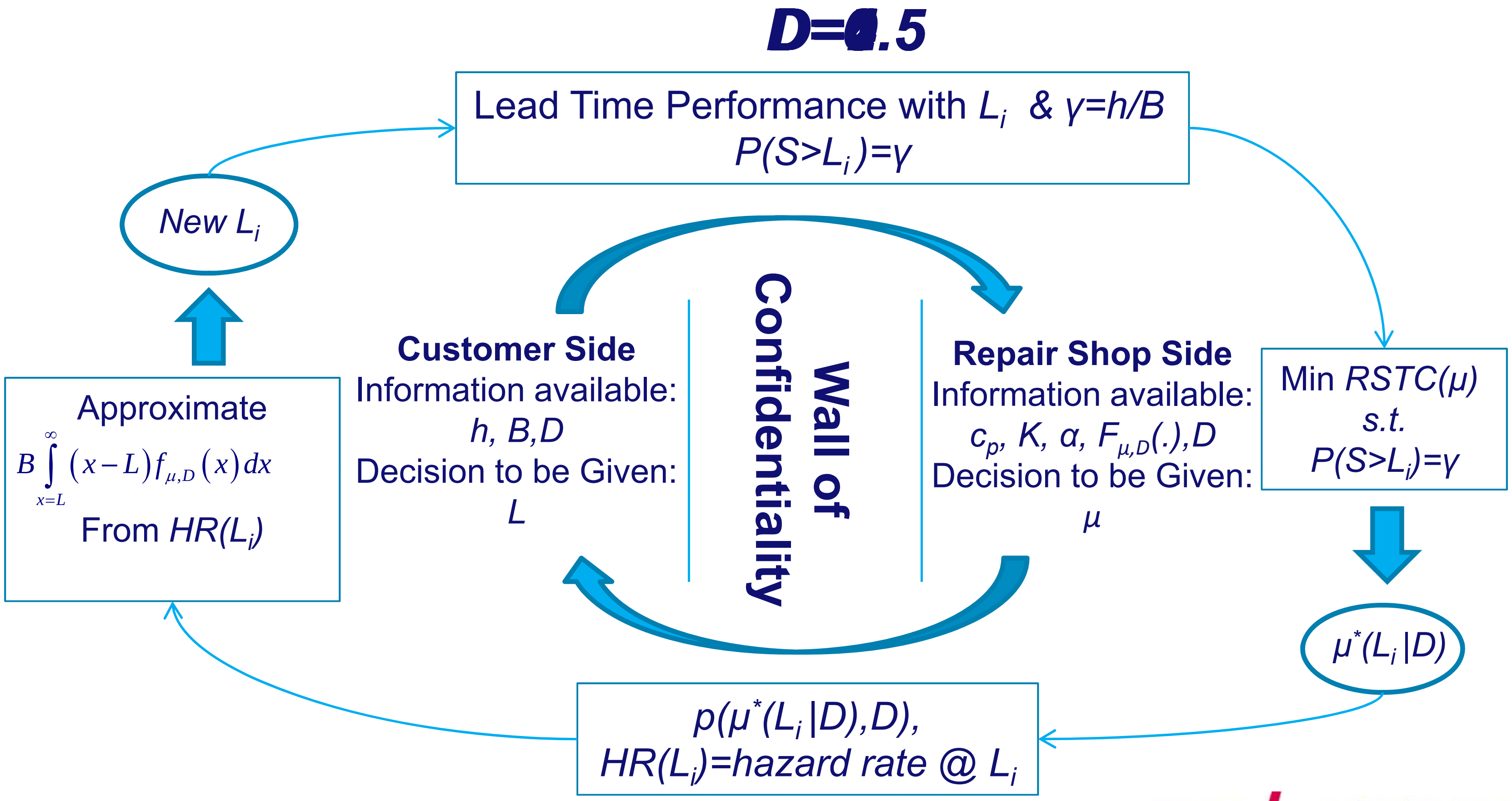
1. **Savings in the fixed component due to economies of scale in transportation.**
2. **Certainty in arrival times → Flexible Capacity Policy**
   - **All the repairs are completed → idle at least until the next period**
   - **Agreement on the Max. number of working hours per week. (*μ*)**
   - **Payment for actual hours worked (λ) (Idle time notion!)**
   - **Compensating Differentials should be reflected on c_p**

$$RSTC(\mu,D) = K/(1+\beta_1 D) + \frac{c_p\left(\frac{\mu}{\lambda}\right)}{1+\beta_2 D}\lambda$$

$$p(\mu,D) = RSTC(\mu,D)/\lambda + \alpha$$

$$TCDT(\mu,D,L) = p(\mu,D) + h\frac{D}{2} + hL + B\int_{x=L}^{\infty}(x-L)f_{\mu,D}(x)\,dx$$

DECOMPOSED DECISION MAKING:



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CONCLUSIONS

1. Maintenance Operations of a Commoditized Capital Goods Environment
2. Hiring a Substitute Machine Alternative
3. Decision Making Framework
   1. Full Information vs. Partial Information
4. Setting the Scene for Strategic Capacity Flexibility
   1. Periodic Customer Admission
5. Applying Labor Economics Concepts to OM models