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The Stochastic Lot Sizing Problem from a Financial Perspective

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Outline

- Motivation
- Formulation of the problem
- Literature overview
- Operational model
- Financial model
- Conclusion

Motivation

- Focus: Stochastic Lot Sizing
  - ‘operational optimal’ decisions become suboptimal under financial considerations
- Finance-Operations Interface
  - Inherent trade-off’s
  - S&OP
- Economic Downturn
  - Financial bottom line
- Shared Resources:
  - Physical: multiple products & setup time
  - Financial: resources consumption, depreciation & revenue

Focus: Stochastic Queueing Models Combined with Lot Sizing

Operational objectives:

- Minimize waiting time
- Maximize throughput
- Minimize wip
- Minimize lead time → competitive advantage

→ influences customer satisfaction

(Kenyon et al, 2005, Kuik & Tielemans, 1998 and 2004)

BUT ….bottom line effect on firm’s value?

Focus: Stochastic Queueing Models Combined with Lot Sizing

Other papers focus on profits and costs such as:
Setup costs,
Inventory costs,
Order costs,
…

BUT not on capital charge, depreciation, revenue and taxes = other elements of the income statement/balance sheet

One of the priorities of today's firm = maximization of shareholder value (Guillén et al, 2006) → EVA®

Problem formulation

Goal of this paper:

- Study the financial implications of mid-term operational decision making

- Maximize shareholder value with an integrated operational-financial model

- Economic Value Added =

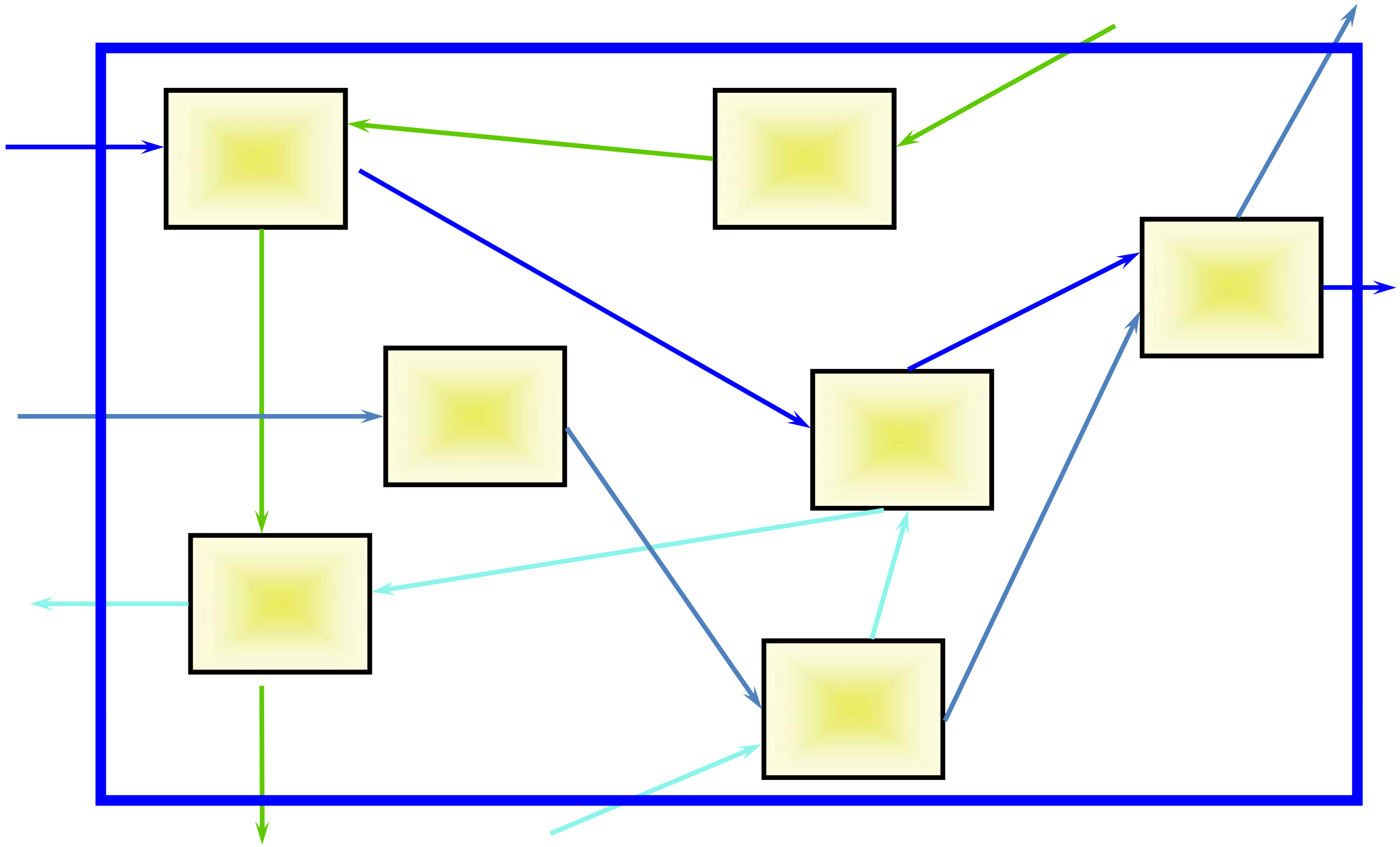
  Net Operating Profit After Taxes – Invested Capital * WACC

Managerial decision making on the midterm level:

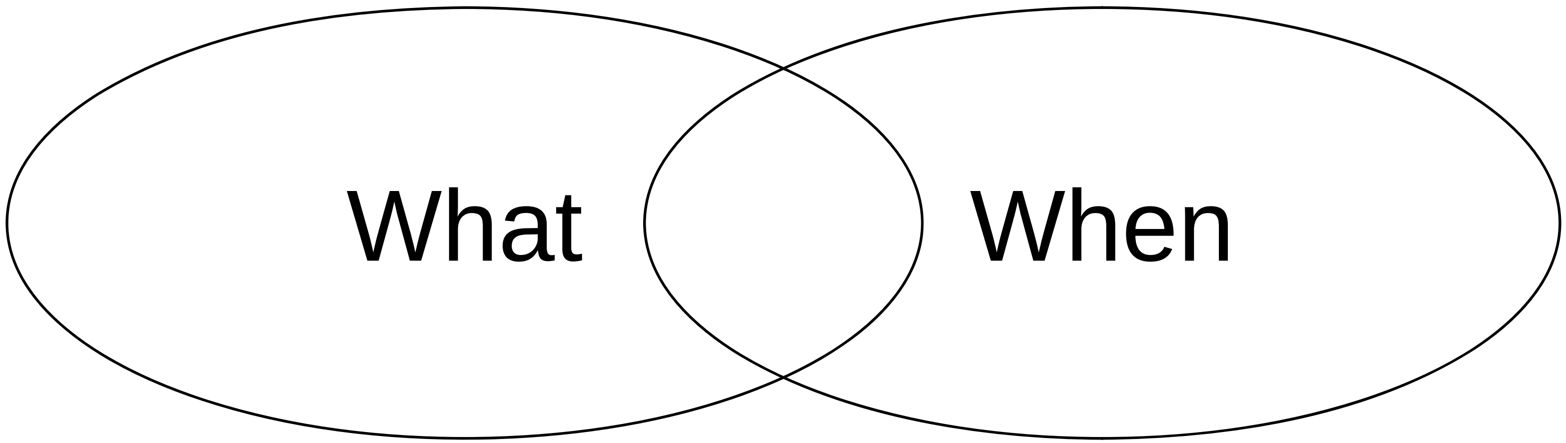
- Batch sizing
- Overtime

Problem formulation

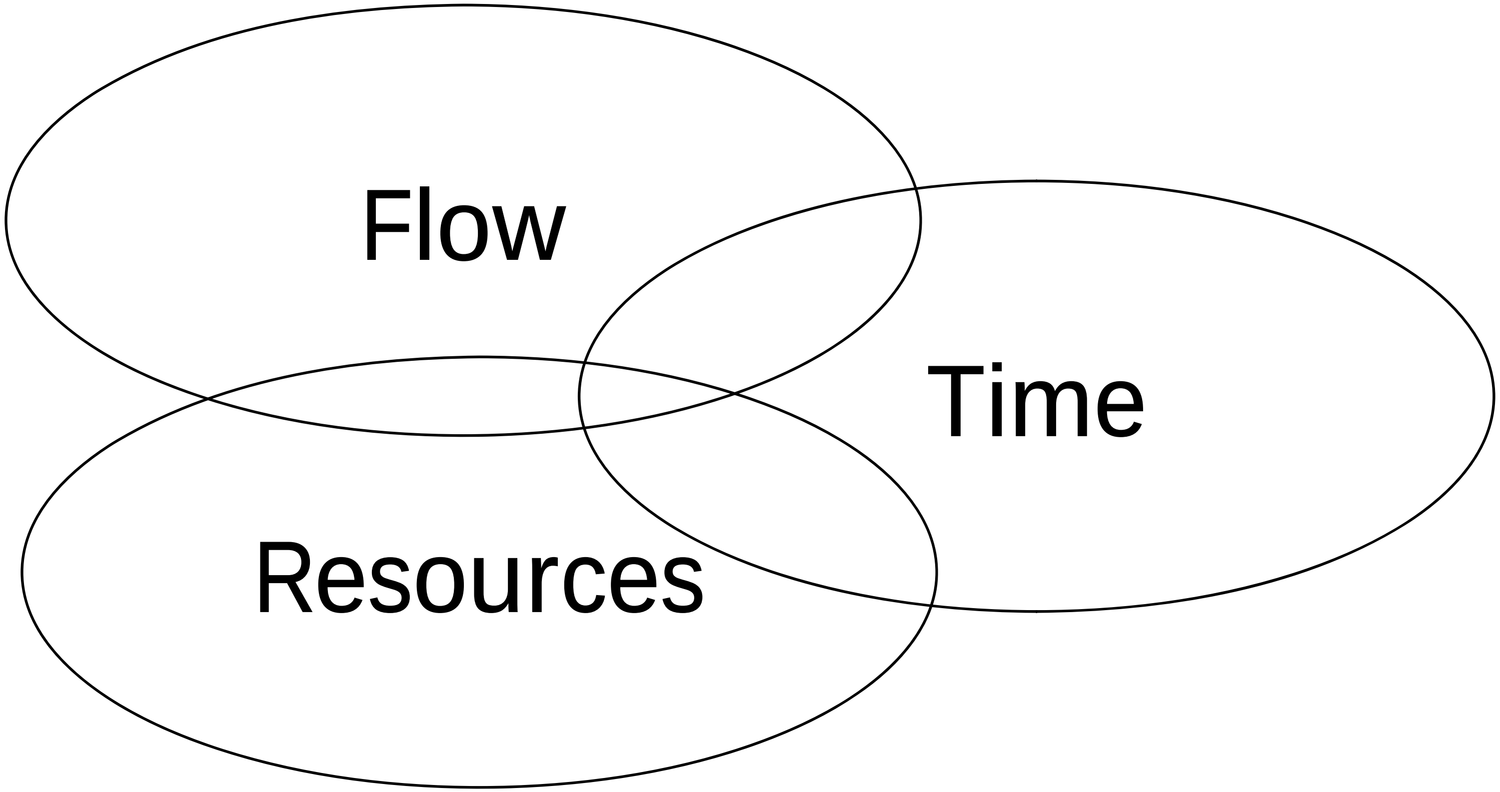
The Physical System: Boundaries, (Shared) Resources and Flows



Basic Dimensions of Planning in Flow Systems



Basic Physical Dimensions



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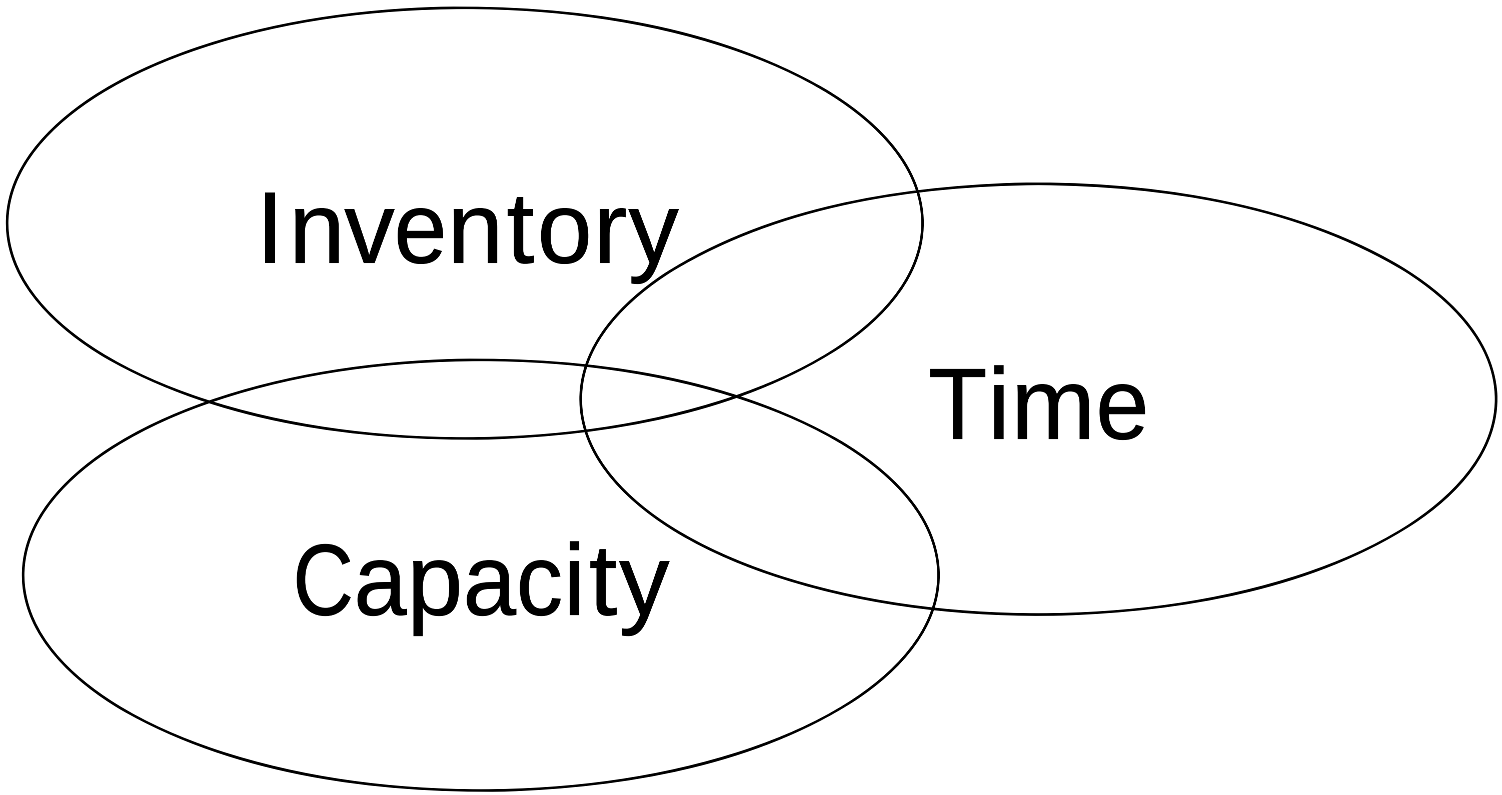
Three Physical Buffers



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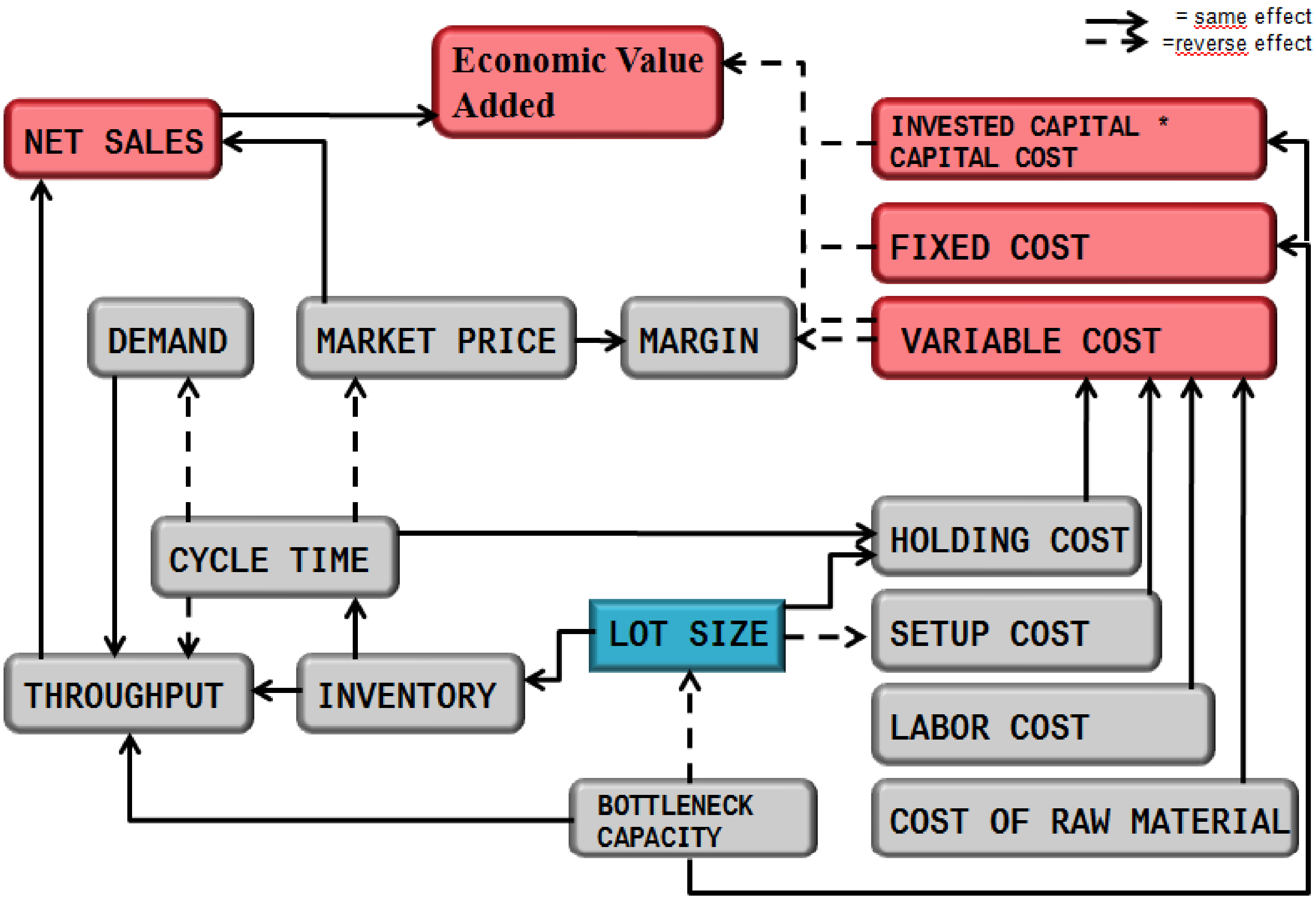
Problem formulation



Literature Overview

Queueing models combined with batching that minimize lead time/waiting time

- Karmarkar et al, 1985 & 1986
- Tielemans & Kuik, 1996
- Lambrecht & Vandaele, 1996
- Kuik & Tielemans, 2004
- Lambrecht et al, 1998
- Fowler et al, 2002

Queueing models combined with batching optimizing costs or profits

- Bertrand, 1985
- Zipkin, 1986
- Hopp et al, 2002
- Missbauer, 2002
- Choi & Enns, 2004

Literature Overview

- **To our knowledge, papers that discuss the integration of operational queueing models and financial models maximizing shareholder value are scarce but …**

- Yi & Reklaitis (2004) present a production planning model that simultaneous takes into account production and financial constraints for a batch-storage network. Taking into account the financial constraints decreased the optimal lot sizes and storage sizes. The authors assume a limited cash availability.

- Guillén et al (2007) derive an integrated model for supply chain management which includes budgetary constraints as well as process operations. Change in equity is optimized in this model.

- **Some papers discuss the inflow and outflow of cash…**

- Dellepiane (2004) focuses on the balancing of cash flows in an integrated financial-operational model
- Badell et al (2004) combine a deterministic cash flow management model with an advanced schedule algorithm using a mixed integer linear programming formulation
- Comelli et al (2008) show how each production plan can be associated with a budget and with financial metrics. In this way, budgeting and planning of the physical flows can be synchronised.

Operational model

The single product single machine stochastic lot-sizing problem (Lambrecht & Vandaele, 1996)

- make-to-order – Job shop – open queueing network
- Individual arrivals instead of batch arrivals
- Process time, setup time, interarrival time = stochastic
- Waiting time in the GI/G/1 queue is approximated (Whitt, 1983)

Objective: Minimize E(W) as a function of Q

E(W) = collecting time + waiting time in queue + setup time + process time

$$E(W) = \frac{\rho'^2 Q\left(c_{\mathrm{ba}}^2 + c_{\mathrm{bs}}^2\right)}{2\lambda(1-\rho')} \exp\left\{\frac{-2(1-\rho')\left(1-c_{\mathrm{ba}}^2\right)^2}{3\rho'\left(c_{\mathrm{ba}}^2 + c_{\mathrm{bs}}^2\right)}\right\} + \frac{Q-1}{2\lambda} + \tau + \frac{Q+1}{2\mu}$$

where:

λ = Individual arrival rate.

μ = Individual processing rate.

τ = Expected setup time.

ρ' = $\lambda(\mu\tau + Q)/(\mu Q)$.

c_{ba}^2 = scv of the batch interarrival time.

c_{bs}^2 = scv of the batch processing time.

The single product single machine stochastic lot-sizing problem (Lambrecht & Vandaele, 1996)

The operational model should be extended with overtime

$\mu' = 1/\underline{X} * \phi$

Operational constraints:

ρ' = occupation rate < 1

Q = lot size ≥ 1

$\phi > 0$

Financial model

$$EVA = NOPAT - IC * WACC,$$
$$NOPAT = (\sum_t NS_t - \sum_t VC_t - D)(1-z),$$
$$VC_t = MC_t + SC_t + WC_t + LC_t,$$
and $$IC = \frac{FA_0 + FA_1}{2} + \frac{C_0 + C_{12}}{2} + \frac{1}{\bar{\bar{Y}}} E(W) r + AR - AP.$$

$$NS_t = p \frac{1}{\bar{\bar{Y}}} e^{-\beta \frac{E(W) - E(W_{industry})}{E(W_{industry})}}$$

➡ Sales price fluctuates as a function of the lead time (Kenyon, 1997, Choi & Enns, 2004)

$$MC_t = \frac{1}{\bar{\bar{Y}}} r,$$

$$SC_t = s \frac{1}{\bar{\bar{Y}}} \frac{1}{Q}.$$

$$WC_t = E(W) \frac{1}{\bar{\bar{Y}}} h_{wip},$$

$$LC_t = lc \times \phi.$$

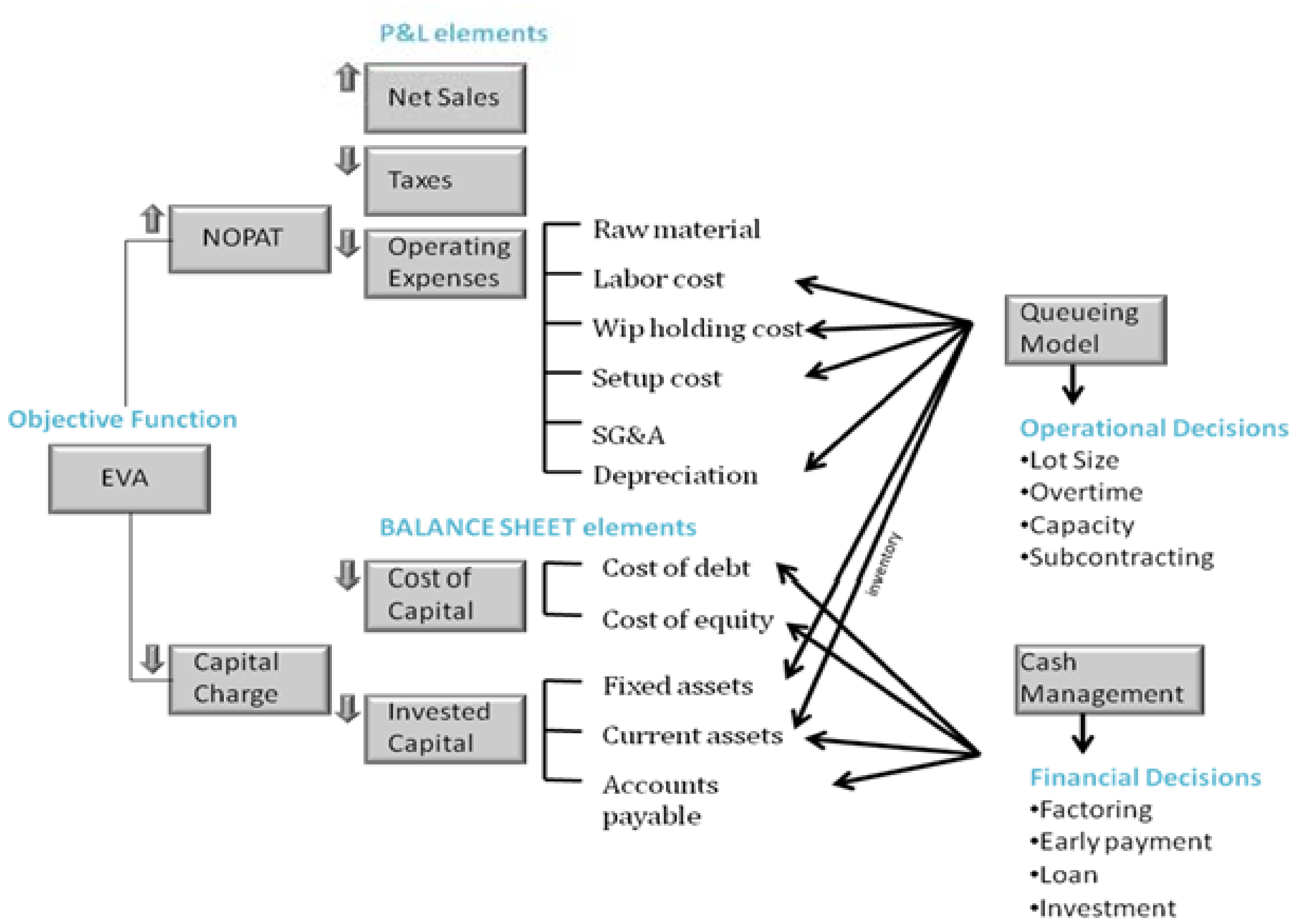
➡ Variable Cost Components

$$C_t = C_{t-1} + NS_{t-1} - MC_{t-1} - SC_t - LC_t - WC_t - STI_t + STI_{t-1}(1+i),$$

➡ Cash Calculation

Financial model

The impact of the operational decisions on the relevant intermediate financial parameters such as labor costs, setup costs, fixed assets, …



Operational & Financial data

	Interarrival time	Setup time	Processing time
Average	1.0	10	0.5
Variance	0.5	10	0.0625
Scv	0.5	0.1	0.25

p = 80	Average industry lead time = 0.05 month
r = 30	FA_0 = 60 000
s = 100	FA_1 = 48 000
hwip = 3	Depreciation = 12 000
lc = 22 000	β = 0.1
WACC = 0.06	C0 = 2000
z = 0.4	

Some results

Optimization 1

	Optimizing Lead Time	Optimizing EVA	Optimizing Cash Availability
EVA	67 396	100 766	100 766
Average lead time	29.22 hours	50.49 hours	50.56 hours
Average waiting time for the batch in queue	1.28 hours	1.72 hours	1.72 hours
Occupation rate	91.2%	95.7%	95.7%
Batch size	24.23	44.86	44.95
Overtime (ϕ)	1	0.68	0.68

All optimizations are performance in C++ using a steepest ascent method

Some results

Optimization 2

	EVA	LOT SIZE	LEAD TIME	OVERTIME
s = 10	111 138	40.67	46.68 hours	0.70
s = 100	100 766	44.86	50.49 hours	0.68
s = 500	63 660	61.82	66.52 hours	0.62

	EVA	LOT SIZE	LEAD TIME	OVERTIME
$\beta = 0.01$	130 643	108.9	116.82 hours	0.56
$\beta = 0.1$	100 766	44.86	50.49 hours	0.68
$\beta = 1$	155 911	20.67	25.15 hours	1.24

Conclusion

- Operational optimization (optimal lot sizes) deviates from the integrated financial-operational optimization
- A distinction is made between the cost of the setup and the opportunity cost of lost production capacity

- Future research:
- Multi product, multi machine case
- Include subcontracting