Maximizing the performance at a sawmill with optimization models and simple heuristics

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Overview

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3. Objective function
4. Mixed integer program
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Overview

Problem description

Given

- More competitors on European saw milling market
- Wood as raw material is more in demand than it used to be
- Variety of products
- Different supply of raw material
- Optimize timber production
- Choosing best cutting patterns for given raw material to produce different timber products

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Goal

$\Rightarrow$ Dealing with inventory of raw material and final products
$\Rightarrow$ Wise selection of raw materials needed

Overview

Cutting patterns

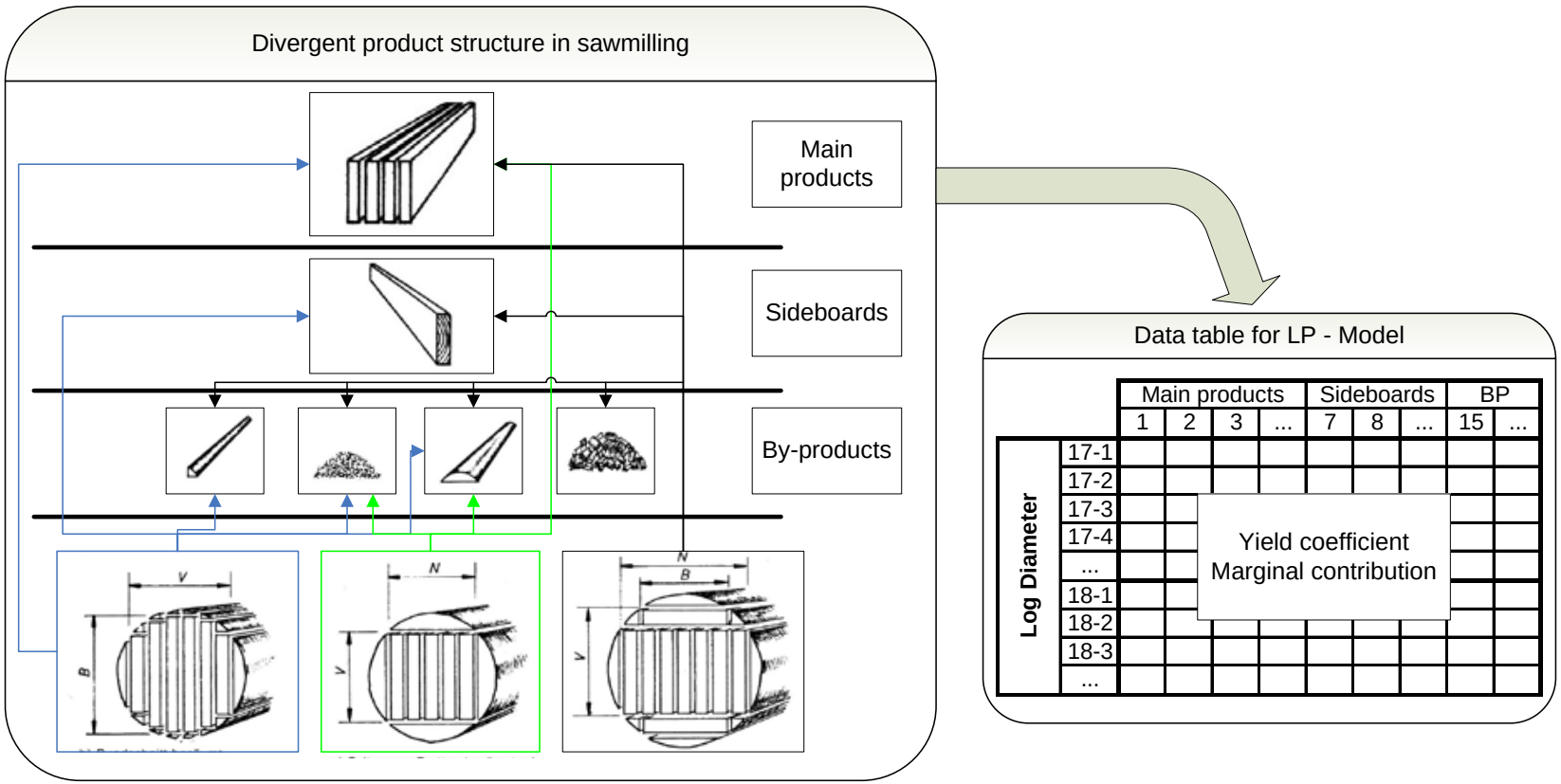


Figure : Different possible cutting patterns given a specific diameter

Overview

Objective function

Maximizing vs. Minimizing

Two different approaches:

- Maximizing the contribution margin
  - Greigeritsch, T. (2009). Neue Methoden zur Planung und Optimierung der Schnittholzproduktion von Nadelholzsägewerken. Gabler Research, Wiesbaden
  - Pastor, R., Altimiras, J., and Mateo, M. (2009). Planning production using mathematical programming: The case of a woodturning company. *Computers & Operations Research*, 36(7):2173–2178
- Minimizing costs
  - Maness, T. C. and Norton, S. E. (2002). Multiple period combined optimization approach to forest production planning. *Scandinavian Journal of Forest Research*, 17:460–471
  - Maturana, S., Pizani, E., and Vera, J. (2010). Scheduling production for a sawmill: A comparison of a mathematical model versus a heuristic. *Computers & Industrial Engineering*, 59:667–674

Overview

Mixed integer program

Indices and decision variables

p	the number of products
c	the number of cutting patterns
d	the number of log diameters/raw material
t	time periods
q	the number of different qualities
h	type of wood
rm_{ctqh}	quantity of raw material of quality q and wood type h processed with cutting pattern c used in period t
id_{dtqh}	inventory of log type d of quality q and wood type h at the end of period t, where id_{d0qh} is the starting inventory at the beginning of period 1
ip_{ptqh}	inventory of product p at the end of period t, where ip_{p0qh} is the starting inventory at the beginning of period 1
b_{ptqh}	back order of product p at the end of period t, where b_{p0qh} is the starting backlog at the beginning of period 1
$feed_{ch}$	quantity of raw material of wood type h processed with cutting pattern c
sp_{pqh}	1, if there is a demand for product p over the considered periods, 0 otherwise

Mixed integer program cont'd

Parameters

Y_{pc}	yield or percentage of the product p obtained after processing raw material with cutting patter c
PA_{dc}	production allocation (0 or 1) 1 if cutting pattern c used for log diameter d, 0 otherwise
DE_{ptqh}	demand for product p in period t of quality q and wood type h
PC_{dqh}	purchasing price of log diameter d with quality q and wood type h
RM_{dtqh}	available raw material, logs with diameter d in period t of quality q and wood type h
VC_{pqh}	variable costs for product p with quality q and wood type h
NSP_{pqh}	net sales price for product p with quality q and wood type h
ICD_d	inventory costs for one unit of log diameter d for one period
ICP_p	inventory costs for one unit of product p for one period
BC_p	backlog costs for one unit of product p for one period
MHT_c	machinery holding time for cutting pattern c
CAP_t	maximal operating time in period t

Mixed integer program cont'd

Objective function

$$\sum_{t\in T}\sum_{p\in P}\sum_{c\in C}\sum_{q\in Q}\sum_{h\in H} NSP_{pqh} * \left(Y_{pc} * rm_{ctqh} + ip_{pt-1qh} - ip_{ptqh}\right) -$$

$$\sum_{t\in T}\sum_{p\in P}\sum_{c\in C}\sum_{q\in Q}\sum_{h\in H} VC_{pqh} * Y_{pc} * rm_{ctqh} -$$

$$\sum_{t\in T}\sum_{d\in D}\sum_{c\in C}\sum_{q\in Q}\sum_{h\in H} PC_{dqh} * RM_{dtqh} -$$

$$\sum_{t\in T}\sum_{d\in D}\sum_{q\in Q}\sum_{h\in H} ICD_d * id_{dtqh} - \sum_{t\in T}\sum_{p\in P}\sum_{q\in Q}\sum_{h\in H} ICP_p * ip_{ptqh} -$$

$$\sum_{t\in T}\sum_{p\in P}\sum_{q\in Q}\sum_{h\in H} BC_p * b_{ptqh} +$$

$$\sum_{d\in D}\sum_{q\in Q}\sum_{h\in H} PC_{dqh} * 0.9 * id_{dTqh} +$$

$$\sum_{t\in T}\sum_{p\in P}\sum_{q\in Q}\sum_{h\in H} ip_{pTqh} * NSP_{pqh} * (0.7 + sp_{pqh} * 0.1)$$

Mixed integer program cont'd

Constraints

$$id_{dtqh} = id_{dt-1qh} + RM_{dt-1qh} - \sum_{c \in C} PA_{dc} * rm_{ctqh}$$

$$\forall t \in T, d \in D, q \in Q, h \in H$$

$$\sum_{c \in C} \sum_{q \in Q} \sum_{h \in H} MHT_c * rm_{ctqh} \leq CAP_t$$

$$\forall t \in T, q \in Q, h \in H$$

$$ip_{ptqh} - b_{ptqh} = ip_{pt-1qh} - b_{bt-1qh} + \sum_{c \in C} Y_{pc} * rm_{ctqh} - DE_{ptqh}$$

$$\forall t \in T, p \in P, q \in Q, h \in H$$

$$\sum_{q \in Q, t \in T} rm_{ctqh} \geq feed_{ch}$$

$$\forall c \in C, h \in H$$

$$rm_{ctqh},\ id_{dtqh},\ ip_{ptqh},\ b_{ptqh} \geq 0$$

$$\forall p \in P, t \in T, c \in C, d \in D, q \in Q, h \in H$$

Overview

Heuristics

Heuristic A - Sawmill heuristic

$L = \{Y_{cp}\}$ set of cutting patterns
sort L according to yield
for $t \in T$ **do**
  while $L.next()$ **do**
    $c = L.cuttingPattern$ and $d = L.diameter$
    if $RM_{dt-1qh} > 0.0$ **then**
      $p = L.product$, $q = RM.quality$ and $h = RM.woodtype$
      if $CAP_t > 0.0$ **then**
        compute cut_{ctqh}
        update CAP_t, $production_{ptqh}$, $demand_{ptqh}$ and $invRM_{dtqh}$
        remove c from L
      end if
    end if
  end while
end for

Heuristics cont'd

Heuristic B - Easy

$L = \{Y_{cp}\}$ set of cutting patterns
sort L according to contribution margin per product
for $t \in T$ **do**
  while $L.next()$ **do**
    $c = L.cuttingPattern$ and $d = L.diameter$
    if $RM_{dt-1qh} > 0.0$ **then**
      $p = L.product$, $q = RM.quality$ and $h = RM.woodtype$
      if $CAP_t > 0.0$ **then**
        compute cut_{ctqh}
        update CAP_t, $production_{ptqh}$, $demand_{ptqh}$ and $invRM_{dtqh}$
        remove c from L
      end if
    end if
  end while
end for

Heuristics cont'd

Heuristic C - Maturana

for $t \in T$ **do**
  $K = \{D_{ptqh}\}$ set of demands
  sort K according to demand
  while $K.next()$ **do**
    $p = K.product$, $q = K.quality$ and $h = K.woodtype$
    L = $\{Y_{cp}\}$ set of cutting patterns
    sort L according to yield
    while $L.next()$ **do**
      $c = L.cuttingPattern$ and $d = PA_{dc}$
      if $RM_{dt-1qh} > 0.0$ **then**
        if $CAP_t > 0.0$ **then**
          compute cut_{ctqh}
          update CAP_t, $production_{ptqh}$, $demand_{ptqh}$ and $invRM_{dtqh}$
          break
        end if
      end if
    end while
  end while
end for

Heuristics cont'd

Heuristic D - Raw material

for $t \in T$ **do**
  $R = \{RM_{dt-1qh}\}$ set of available raw material
  sort R according to raw material
  while $R.next()$ **do**
    $d = R.diameter$, $q = R.quality$ and $h = R.woodtype$
    P set of products
    sort P according to contribution margin per product m^3
    while $P.next()$ **do**
      $p = P.product$
      if $DE_{ptqh} > 0.0$ **then**
        $L = \{Y_{cp}\}$ set of cutting patterns
        sort L according to contribution margin per product
        while $L.next()$ **do**
          if $CAP_t > 0.0$ **then**
            compute cut_{ctqh}
            update CAP_t, $production_{ptqh}$, $demand_{ptqh}$ and $invRM_{dtqh}$
            break
          end if
        end while
      end if
    end while
  end while
end for

Overview

Numerical experiments

Preparations

	Standard	Alterations
Backlog cost	100,000	5
Variable cost	$\{0, 5, 20, 29\}$	$\{0, 5, 20\}$
Diameter	11 - 51 cm	16 - 42 cm
Raw material	100 %	110 %
By products	given demand	total production sold
Objective function	no storage validation inventory at period T	storage validation sales from stock

Numerical experiments

Phases

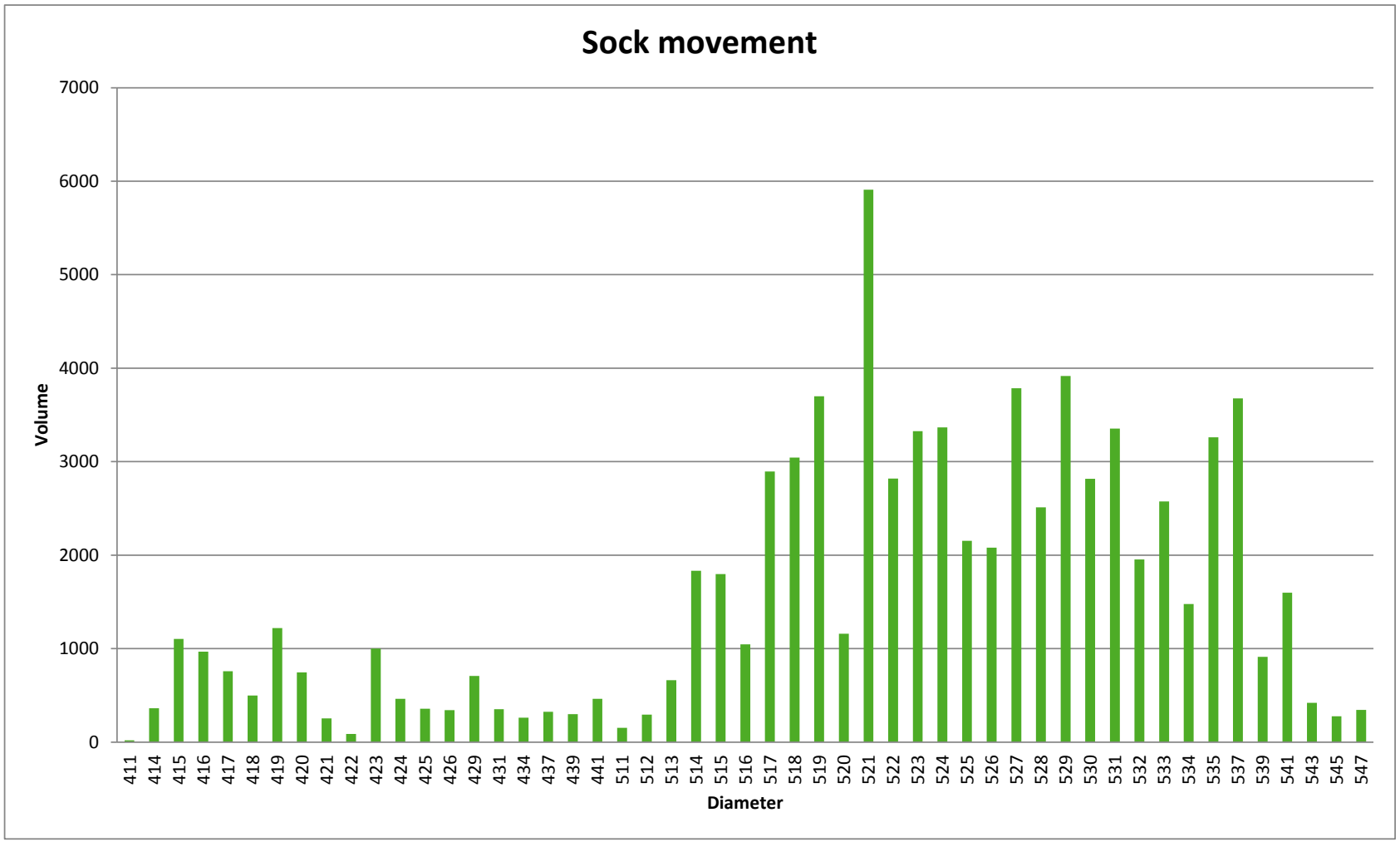
Phase 0 Solve heuristics and optimization with altered backlog cost and new objective function

Phase 1 Cut down on variable costs

Phase 2 Stop buying diameters which are either too small or big for the saw

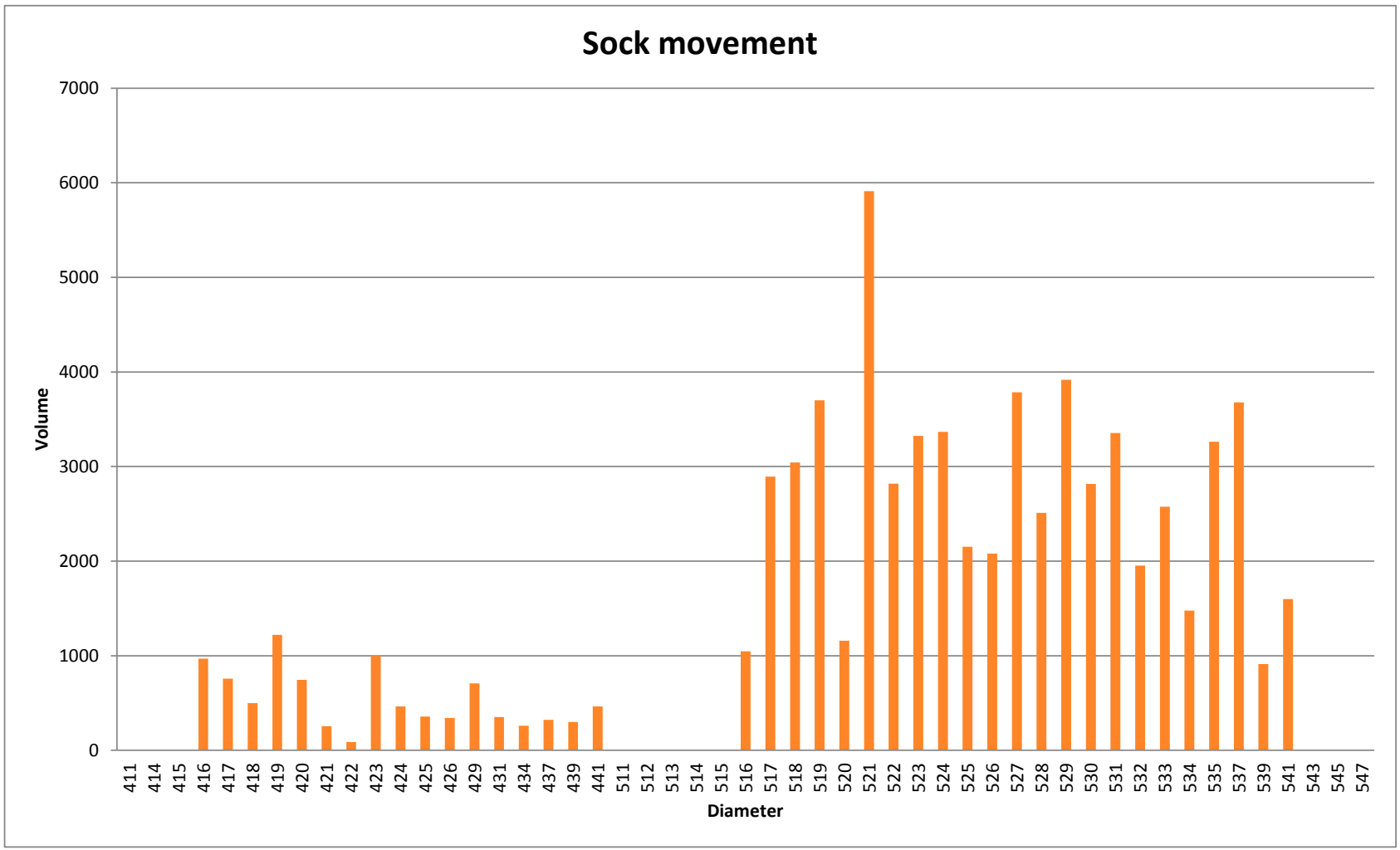
Numerical experiments cont'd

Diameter with irregular sizes



Numerical experiments cont'd

Regular diameters



Numerical experiments cont'd

Solutions comparison

Contribution margin

	Phase 0	Phase 1	Phase 2
Heuristic A	49,492	313,213	390,376
Heuristic B	-613,462	606,671	949,153
Heuristic C	-58,926	115,736	821,109
Heuristic D	1,546,845	737,754	1,622,773
Optimization	1,782,975	1,918,522	1,842,737

Numerical experiments cont'd

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Share of the optimal solution in %

	Phase 0	Phase 1	Phase 2
Heuristic A	2.78	16.33	21.18
Heuristic B	-34.41	31.62	51.51
Heuristic C	-3.30	6.06	44.56
Heuristic D	86.76	38.45	88.06
Optimization	100	100	100

Numerical experiments cont'd

Average costs compared to average revenues

Average costs

	Costs €	Share %
Inventory Raw material	6,217	0.09
Inventory Products	6,000	0.09
Backlog	21,047	0.30
Raw material	5,970530	86.36
Variable production	909,685	13.16
$\sum$	6,913,480	100

Numerical experiments cont'd

Average costs compared to average revenues

Average costs

	Costs €	Share %
Inventory Raw material	6,217	0.09
Inventory Products	6,000	0.09
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Average revenues

	Revenues €	Share %
Net revenue	6,624,062	75.26
Storage value raw material	22,398	0.25
Storage value products	2,144,554	24.48
$\sum$	8,801,015	100

Overview

Future work

Outlook

- Vary demand and given raw material
  - Increase/decrease demand
  - Increase/decrease available raw material
  - Different quality and diameter distributions
- Compute different scenarios
  - One period
  - More periods
  - More periods, one at a time
  - Rolling horizons
- Randomized heuristic solution approach
  - Start various randomized heuristics
  - Parallel start

Thank you for your attention!

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