

TIMO



Amsterdam

May 31, 2013

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TIMO

- Thrombocytes
Inventory
Management
Optimizer
- A Decision Support System


Overview

- History
- Platelets
 - ◆ Blood Bank
 - ★ FIFO
 - ★ LIFO
 - ★ Compatibility
 - ◆ Hospital
- Red Cells

History

- PhD Rene Haijema 2003-2008 (UVA)
- Sanquin
 - ◆ Cees Smit Sibinga
 - ◆ Wim de Kort
 - ◆ Eric Jansen
- UVA
 - ◆ Nico van Dijk
 - ◆ Nikky Kortbeek
 - ◆ Michiel Janssen

Platelets (Perishable)

- Short shelf life in relation to demand
- Unlimited shelf life
  Simple strategies
- If perishable, optimal strategies are highly complex

Decision structure: 24 hour model (simplification)

- At time T (e.g. 8.00 am) stocks are counted
- Next the production decision is taken (based on replenishment level and current stock)
- During the day platelets are issued to the hospitals
- The next day these pools are available

Back to complexity (Shelf life 7 days)

- State (situation) can be written as

$(n_1, n_2, n_3, n_4, n_5, n_6, n_7)$

- States

$(20, 10, 10, 10, 20, 20, 20)$

and

$(20, 20, 20, 20, 10, 10, 10)$

are different

Fortunately

- Using only the total inventory one can obtain already a very good strategy

(See: Thesis Haijema)

Therefore, TIMO computes

- The best **Order-Up-To** strategy

$(S_{\text{Mo}}, S_{\text{Tu}}, S_{\text{We}}, S_{\text{Th}}, S_{\text{Fr}}, S_{\text{Sa}}, S_{\text{Su}})$

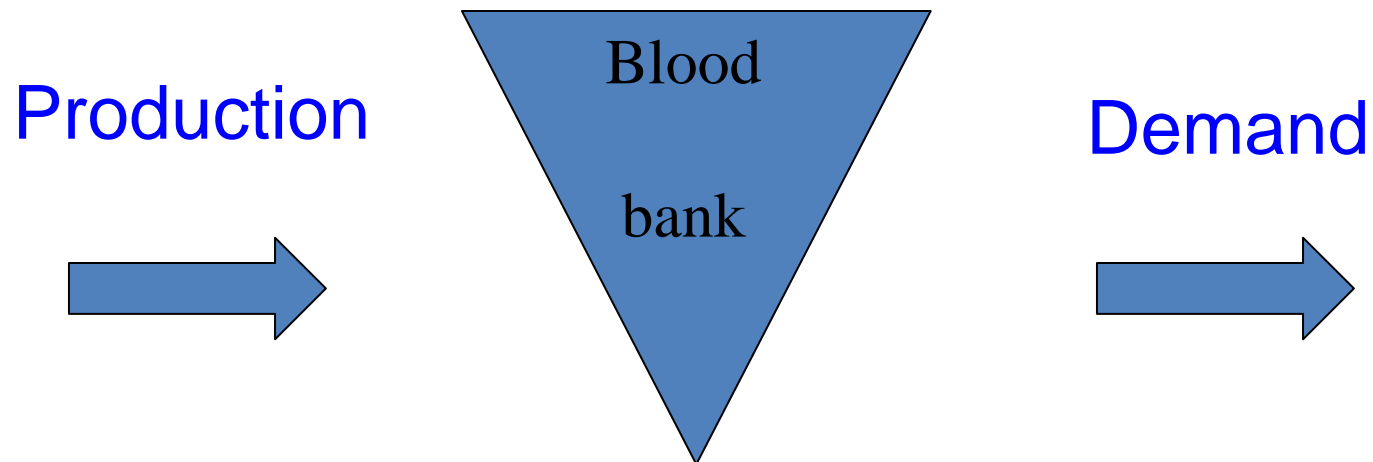
The Netherlands

- Compatibility (Red Cell)
- Mainly buffy coats (> 90 percent)
- Uses buffy coats from 60 to 70 percent of the WB (T&B) donations

Using only 60 to 70 percent implies

- An ample supply of buffy coats to make pools
- The freedom to choose, so blood groups O and A
- That compatibility ‘allows full aggregation’
Verified in earlier (very detailed) simulations. Also depends on the size and details of the Dutch blood bank case. See thesis Haijema.

Focus: Central bloodbank



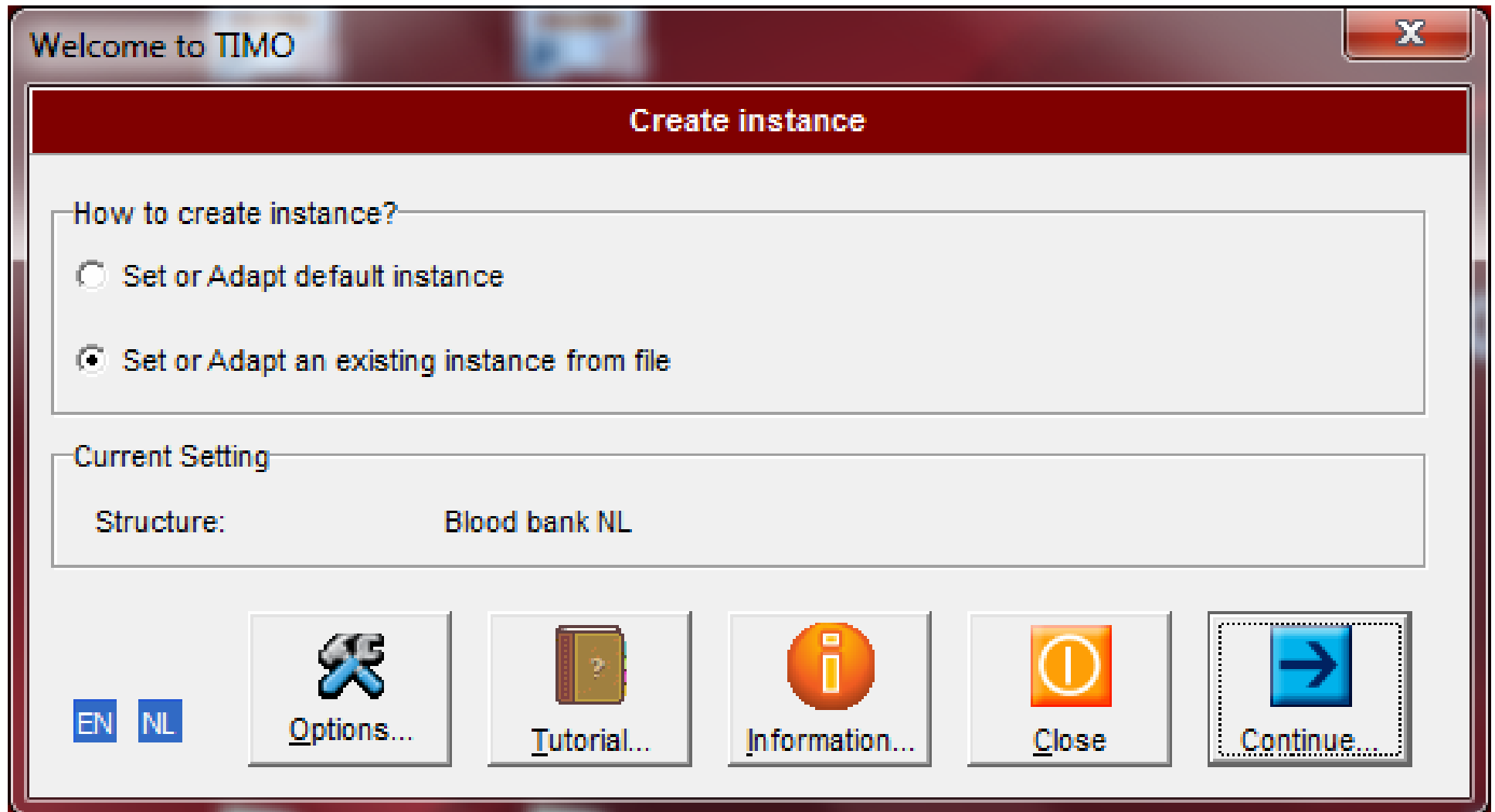
Focus: Bloodbank

- ◆ Stock keeping at the blood bank
- ◆ Production at the blood bank
- ◆ All hospital demand satisfied by the blood bank
- ◆ Only statistical information !
 - ★ mean and standard deviation for every day of the week
 - ★ no information about what will happen in the hospitals tomorrow

TIMO: Input data?

- Demand: mean and standard deviation for each day of the week
- Shelf life
- Production capacity for each day
- Issuing policy, e.g., FIFO
- Costs per shortage and per outdate

TIMO



Modify Demand Characteristics

Select Demand | Demand in units |

Shelf Life

Shelf life including production day: 7 days.

Issuing policy for Any demand

Issuing policy: FIFO

Type of demand

- ☒ Any Demand Only
- ☐ Young and Any Demand



Close



Back



Continue...

Modify Demand Characteristics

Select Demand Demand in units

Total demand in units

	Demand ->	Mean	StDev
1	Monday	60	15
2	Tuesday	60	15
3	Wednesday	60	15
4	Thursday	60	15
5	Friday	60	15
6	Saturday	30	10
7	Sunday	30	10



Close



Back



Continue...

Problem Data

Modify Problem Data

Problem Parameters

Storage capacity

Storage capacity: donor units.

Costs parameters

Shortage Costs:

Outdating Costs:

Mismatch Costs:

Production Capacity

Regular

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
ProdCap	0	250	250	250	250	125	0

☒ Regular

☐ Irregular



Close



Back



Save Input...



Optimize...



Simulate...

Simulation Control

Run Control

Simulation horizon: 520 weeks.

☐ Disable Animation

Pause at

☐ Next day

☐ Next outdating

☐ Next shortage

☐ Next mismatch

Random seed value: 0



Reset



Start



Finished



Generate excel output

Results

Replenishment rule (Monday - Sunday):

Regular

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Total	0	224	227	217	244	271	0

Visualise stock transition

Statistics

Special Events

All Transitions

Plot Demand Distributions

Performance

Average costs per week 7.69

Outdating frequency 3 (= 0.08% in days)

Outdating volume 40 (= 0.02% of production)

Shortage frequency 0 (= 0% in days)

Shortage volume 0 (= 0% of demand)

Mismatching frequency 0 (= 0% in days)

Mismatching volume 0 (= 0% of demand Young)

Age in days counted from date of donation (min. age = 2 days)

Mean issuing age 4.54

Distribution Issuing Age

2	3	4	5	6	7
1.0%	15.0%	29.0%	39.0%	15.0%	1.0%



Restart



Close

Simulation Control

Run Control

Simulation horizon: 520 weeks.

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Pause at

☐ Next day☐ Next outdating☐ Next shortage☐ Next mismatch

Random seed value: 0



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Finished



Generate excel output

Results

Replenishment rule (Monday - Sunday):

Regular

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Total	0	224	227	217	244	271	0

Visualise stock transition | Statistics | Special Events | All Transitions | Plot Demand Distributions

Day number	Day	Type	Number of pools
872	Thu	Outdating	3 pools
873	Fri	Outdating	20 pools
2672	Fri	Outdating	17 pools



Restart



Close

Simulation Control

Run Control

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Start



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Generate excel output

Results

Replenishment rule (Monday - Sunday):

Regular

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Total	0	224	227	217	244	271	0

Visualise stock transition | Statistics | Special Events | All Transitions | Plot Demand Distributions

	Day	Present Stock	Total St...	Prod.	Deman...	Deman...	Outdati...	Shortage	Mismat
851	Thu	(75, 67, 0, 0, 26, 0)	168	49	0	99	0	0	
852	Fri	(49, 69, 0, 0, 0, 0)	118	126	0	66	0	0	
853	Sat	(126, 49, 3, 0, 0, 0)	178	93	0	24	0	0	
854	Sun	(93, 126, 28, 0, 0, 0)	247	0	0	33	0	0	
855	Mon	(0, 93, 121, 0, 0, 0)	214	0	0	62	0	0	
856	Tue	(0, 0, 93, 59, 0, 0)	152	72	0	50	0	0	
857	Wed	(72, 0, 0, 93, 9, 0)	174	53	0	64	0	0	
858	Thu	(53, 72, 0, 0, 38, 0)	163	54	0	51	0	0	
859	Fri	(54, 53, 59, 0, 0, 0)	166	78	0	49	0	0	
860	Sat	(78, 54, 53, 10, 0, 0)	195	76	0	34	0	0	
861	Sun	(76, 78, 54, 29, 0, 0)	237	0	0	30	0	0	
862	Mon	(0, 76, 78, 53, 0, 0)	207	0	0	58	0	0	
863	Tue	(0, 0, 76, 73, 0, 0)	149	75	0	65	0	0	
864	Wed	(75, 0, 0, 76, 8, 0)	159	68	0	50	0	0	
865	Thu	(68, 75, 0, 0, 34, 0)	177	40	0	66	0	0	
866	Fri	(40, 68, 43, 0, 0, 0)	151	93	0	44	0	0	
867	Sat	(93, 40, 67, 0, 0, 0)	200	71	0	19	0	0	
868	Sun	(71, 93, 40, 48, 0, 0)	252	0	0	21	0	0	
869	Mon	(0, 71, 93, 40, 27, 0)	231	0	0	37	0	0	
870	Tue	(0, 0, 71, 93, 30, 0)	194	30	0	33	0	0	
871	Wed	(30, 0, 0, 71, 90, 0)	191	36	0	46	0	0	
872	Thu	(36, 30, 0, 0, 71, 44)	181	36	0	41	3	0	
873	Fri	(36, 36, 30, 0, 0, 71)	173	71	0	51	20	0	
874	Sat	(71, 36, 36, 30, 0, 0)	173	98	0	27	0	0	
875	Sun	(98, 71, 36, 36, 3, 0)	244	0	0	28	0	0	
876	Mon	(0, 98, 71, 36, 11, 0)	216	0	0	57	0	0	



Restart



Close

- LIFO instead of FIFO

Simulation Control

Run Control

Simulation horizon: 520 weeks.

☐ Disable Animation

Pause at

- ☐ Next day
☐ Next outdating
☐ Next shortage
☐ Next mismatch

Random seed value: 0



Reset



Start



Finished



Generate excel output

Results

Replenishment rule (Monday - Sunday):

Regular

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Total	0	224	227	217	244	271	0

Visualise stock transition

Statistics

Special Events

All Transitions

Plot Demand Distributions

Performance

Average costs per week 11631.73

Outdating frequency 1180 (= 32.42% in days)

Outdating volume 48630 (= 20.82% of production)

Shortage frequency 119 (= 3.27% in days)

Shortage volume 2371 (= 1.27% of demand)

Mismatching frequency 0 (= 0% in days)

Mismatching volume 0 (= 0% of demand Young)

Age in days counted from date of donation (min. age = 2 days)

Mean issuing age 2.76

Distribution Issuing Age

2	3	4	5	6	7
62.0%	17.0%	7.0%	13.0%	1.0%	1.0%



Restart



Close

Simulation Control

Run Control

Simulation horizon: 520 weeks.

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Pause at

- ☐ Next day
- ☐ Next outdating
- ☐ Next shortage
- ☐ Next mismatch

Random seed value: 0



Reset



Start



Finished



Generate excel output

Results

Replenishment rule (Monday - Sunday):

Regular

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Total	0	155	153	157	202	226	0

Visualise stock transition

Statistics

Special Events

All Transitions

Plot Demand Distributions

Performance

Average costs per week 5932.12

Outdating frequency 958 (= 26.32% in days)

Outdating volume 16512 (= 8.22% of production)

Shortage frequency 204 (= 5.60% in days)

Shortage volume 2867 (= 1.53% of demand)

Mismatching frequency 0 (= 0% in days)

Mismatching volume 0 (= 0% of demand Young)

Age in days counted from date of donation (min. age = 2 days)

Mean issuing age 2.91

Distribution Issuing Age

2	3	4	5	6	7
61.0%	14.0%	5.0%	14.0%	4.0%	2.0%



Restart



Close



- More random demand

Modify Demand Characteristics

Select Demand

Demand in units

	Demand ->	Mean	StDev
1	Monday	60	30
2	Tuesday	60	30
3	Wednesday	60	30
4	Thursday	60	30
5	Friday	60	30
6	Saturday	30	20
7	Sunday	30	20



Close



Back



Continue...

Simulation Control

Run Control

Simulation horizon: 520 weeks.

☐ Disable Animation

Pause at

☐ Next day☐ Next outdating☐ Next shortage☐ Next mismatch

Random seed value: 0



Reset



Start



Finished



Generate excel output

Results

Replenishment rule (Monday - Sunday):

Regular

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Total	0	258	256	256	268	291	0

Visualise stock transition

Statistics

Special Events

All Transitions

Plot Demand Distributions

Performance

Average costs per week 1225.77

Outdating frequency 161 (= 4.42% in days)

Outdating volume 3249 (= 1.71% of production)

Shortage frequency 17 (= 0.47% in days)

Shortage volume 625 (= 0.33% of demand)

Mismatching frequency 0 (= 0% in days)

Mismatching volume 0 (= 0% of demand Young)

Age in days counted from date of donation (min. age = 2 days)

Mean issuing age 4.95

Distribution Issuing Age

2	3	4	5	6	7
3.0%	11.0%	20.0%	30.0%	25.0%	11.0%



Restart



Close

So we have seen that TIMO

- Computes the order-up-to strategies
- Gives detailed insight into performance
- Also helps you to live with uncertainties

TIMO can also quantify the value of

- a longer shelf life
- additional capacity in and around weekend

Compatibility (Blood Bank)

- Example: Total demand **600** per week
 - ◆ Very small (AB neg) 1%: **6** per week
 - ◆ Small (B neg, AB pos) 3%: **18** per week
 - ◆ Medium (A neg, B pos, O neg) 8%: **48** per week

Costs:

- Shortage is a lesser problem if it can be solved with a compatible blood group.
- Outdating for a small blood group is only a small part of the total outdating.
- Let us choose:
 - ◆ Costs shortage 10
 - ◆ Costs outdating 100

- Start with very small demand (1%)

Demand Characteristics

Modify Demand Characteristics

Select Demand

Demand for pools of any age

	Demand ->	Mean	StDev
1	Monday	1	1.2
2	Tuesday	1	1.2
3	Wednesday	1	1.2
4	Thursday	1	1.2
5	Friday	1	1.2
6	Saturday	0.5	0.8
7	Sunday	0.5	0.8



Close



Back



Continue...

Problem Data

Modify Problem Data

Problem Parameters | Solver | Simulator

Storagecapacity

Storage capacity: donor units.

Costs parameters

Shortage Costs:

Outdating Costs:

Mismatch Costs:

Production Capacity

Regular

Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
ProdCap	0	3	3	3	3	3	0

☒ Regular

☐ Irregular



Close



Back



Save Input...



Optimize...



Simulate...

Simulation Control

Run Control

Simulation horizon: 520 weeks.

☐ Disable Animation

Pause at

- ☐ Next day
☐ Next outdating
☐ Next shortage
☐ Next mismatch

Random seed value: 0



Reset



Start



Finished



Generate excel output

Results

Replenishment rule (Monday - Sunday):

Regular

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Total	0	1	2	2	1	2	0

Visualise stock transition Statistics Special Events All Transitions Plot Demand Distributions

Performance

Average costs per week 38.23

Outdating frequency 57 (= 1.57% in days)

Outdating volume 64 (= 3.51% of production)

Shortage frequency 826 (= 22.69% in days)

Shortage volume 1348 (= 43.40% of demand)

Mismatching frequency 0 (= 0% in days)

Mismatching volume 0 (= 0% of demand Young)

Age in days counted from date of donation (min. age = 2 days)

Mean issuing age 3.22

Distribution Issuing Age

2	3	4	5	6	7
40.0%	28.0%	14.0%	8.0%	6.0%	3.0%



Restart



Close

- Continue with small demand (3 %)

Demand Characteristics

Modify Demand Characteristics

Select Demand

Demand for pools of any age

	Demand ->	Mean	StDev
1	Monday	3	2
2	Tuesday	3	2
3	Wednesday	3	2
4	Thursday	3	2
5	Friday	3	2
6	Saturday	1.5	1.5
7	Sunday	1.5	1.5



Close



Back



Continue...

Simulation Control

Run Control

Simulation horizon: 520 weeks.

☐ Disable Animation

Pause at

- ☐ Next day
- ☐ Next outdating
- ☐ Next shortage
- ☐ Next mismatch

Random seed value: 0



Reset



Start



Finished



Generate excel output

Results

Replenishment rule (Monday - Sunday):

Regular

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Total	0	8	9	9	8	10	0

Visualise stock transition

Statistics

Special Events

All Transitions

Plot Demand Distributions

Performance

Average costs per week 25.94

Outdating frequency 35 (= 0.96% in days)

Outdating volume 57 (= 0.66% of production)

Shortage frequency 349 (= 9.59% in days)

Shortage volume 779 (= 8.31% of demand)

Mismatching frequency 0 (= 0% in days)

Mismatching volume 0 (= 0% of demand Young)

Age in days counted from date of donation (min. age = 2 days)

Mean issuing age 3.57

Distribution Issuing Age

2	3	4	5	6	7
25.0%	28.0%	23.0%	14.0%	7.0%	2.0%



Restart



Close

- Next consider medium demand (8 %)
 - ◆ (Shortage costs again at 10)

Modify Demand Characteristics

Select Demand

Demand for pools of any age

	Demand ->	Mean	StDev
1	Monday	8	3
2	Tuesday	8	3
3	Wednesday	8	3
4	Thursday	8	3
5	Friday	8	3
6	Saturday	4	2.5
7	Sunday	4	2.5



Close



Back



Continue...

Simulation Control

Run Control

Simulation horizon: 520 weeks.

☐ Disable Animation

Pause at

☐ Next day☐ Next outdating☐ Next shortage☐ Next mismatch

Random seed value: 0



Reset



Start



Finished



Generate excel output

Results

Replenishment rule (Monday - Sunday):

Regular

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Total	0	27	27	28	26	31	0

Visualise stock transition

Statistics

Special Events

All Transitions

Plot Demand Distributions

Performance

Average costs per week 6.65

Outdating frequency 7 (= 0.19% in days)

Outdating volume 18 (= 0.07% of production)

Shortage frequency 47 (= 1.29% in days)

Shortage volume 166 (= 0.67% of demand)

Mismatching frequency 0 (= 0% in days)

Mismatching volume 0 (= 0% of demand Young)

Age in days counted from date of donation (min. age = 2 days)

Mean issuing age 3.96

Distribution Issuing Age

2	3	4	5	6	7
10.0%	26.0%	32.0%	24.0%	8.0%	1.0%



Restart



Close

Results

Per week	Outdating %	Shortages %
6 (AB-)	3.5	22.7
18 (AB+,B-)	0.7	8.3
48 (B+,A-,O-)	0.1	0.7

So, for (the scale of) this example

- For **very small** demand one gets a few percent outdated and many compatible deliveries
- For **small** demand most of the deliveries will be identical
- For **medium** demand outdated is almost zero with almost only identical deliveries



- Hospital

Hospital

- Differences?
 - ◆ Demand low, thus more variability
 - ◆ Shelf life in practice shorter
 - ◆ Shortages are a lesser problem
 - ◆ An order is available almost immediately

- Back to the Blood Bank in order to deal with Hospital inventories

Modify Demand Characteristics

Select Demand | Demand in units |

Shelf Life

Shelf life including production day: 7 days.

Issuing policy for Any demand

Issuing policy:

FIFO

Type of demand

- ☐ Any Demand Only
- ☒ Young and Any Demand

Issuing policy for Young demand

Issuing policy:

FIFOR

Units are young until day [min = 2]:

4

☒ Issue older platelets in case of no young available

How to provide Young distribution?

- ☐ Provide mean and StDev for Young and Any separately
- ☒ Provide mean and StDev for Total

30 % Young



Close



Back



Continue...

Simulation Control

Run Control

Simulation horizon: 520 weeks.

☐ Disable Animation

Pause at:

- ☐ Next day
- ☐ Next outdating
- ☐ Next shortage
- ☐ Next mismatch

Random seed value: 0



Reset



Start



Finished



Generate excel output

Results

Replenishment rule (Monday - Sunday):

Regular

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Total	0	219	214	212	222	248	0

Visualise stock transition | Statistics | Special Events | All Transitions | Plot Demand Distributions

Performance

Average costs per week 90.77

Outdating frequency 22 (= 0.60% in days)

Outdating volume 252 (= 0.13% of production)

Shortage frequency 5 (= 0.14% in days)

Shortage volume 44 (= 0.02% of demand)

Mismatching frequency 0 (= 0% in days)

Mismatching volume 0 (= 0% of demand Young)

Age in days counted from date of donation (min. age = 2 days)

Mean issuing age 4.23

Distribution Issuing Age

2	3	4	5	6	7
7.0%	19.0%	36.0%	24.0%	12.0%	2.0%



Restart



Close

Template1 [Compatibiliteitsmodus] - Microsoft Excel

	A	B	C	D
23				
24	OUTPUT	Replenishment rule		(0, 219, 214, 212, 222, 248, 0)
25		Average costs per week		78.48
26				
27		Shortage % in volume	Young	0.06%
28			Any	0%
29			Total	0.02%
30		Shortage % in days	Young	0.10%
31			Any	0.01%
32			Total	0.11%
33				
34		Outdating % in volume		0.12%
35		Outdating % in days		0.55%
36				
37		Mismatch % in volume	Young	0%
38		Mismatch % in days	Young	0%
39				
40		Average issuing age	Young	3.32
41			Any	4.6
42			Total	4.22
43				
44		Issuing Age distribution	Young	(19.0%, 31.0%, 51.0%, 0.0%, 0.0%, 0.0%)
45			Any	(1.0%, 14.0%, 30.0%, 34.0%, 17.0%, 3.0%)

Template

Gereed

100%

Modify Demand Characteristics

Select Demand

Demand in units

	Demand ->	Mean	StDev
1	Monday	6	3
2	Tuesday	6	3
3	Wednesday	6	3
4	Thursday	6	3
5	Friday	6	3
6	Saturday	3	2
7	Sunday	3	2



Close



Back



Continue...

Problem Data

Modify Problem Data

Problem Parameters



Costs parameters

Shortage Costs:

Outdating Costs:

Mismatch Costs:

Ordering and Delivery

Ordering days:

☒ Monday
 ☒ Tuesday
 ☒ Wednesday
 ☒ Thursday
☒ Friday
 ☒ Saturday
 ☐ Sunday

Delivery with age:

	1	2	3	4	5	6
Age (%)	19	31	50	0	0	0



Close



Back



Save Input...



Optimize...



Simulate...

Simulation Control

Run Control

Simulation horizon: 520 weeks.

☐ Disable Animation

Pause at

- ☐ Next day
- ☐ Next outdating
- ☐ Next shortage
- ☐ Next mismatch

Random seed value: 0



Reset



Start



Finished



Generate excel output

Results

Replenishment rule (Monday - Sunday):

Regular

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Total	14	14	13	12	12	12	0

Visualise stock transition

Statistics

Special Events

All Transitions

Plot Demand Distributions

Performance

Average costs per week 50.19

Outdating frequency 71 (= 1.95% in days)

Outdating volume 159 (= 0.85% of production)

Shortage frequency 53 (= 1.46% in days)

Shortage volume 102 (= 0.55% of demand)

Mismatching frequency 0 (= 0% in days)

Mismatching volume 0 (= 0% of demand Young)

Age in days counted from date of donation (min. age = 2 days)

Mean issuing age 4.66

Distribution Issuing Age

1	2	3	4	5	6
3.0%	10.0%	32.0%	32.0%	17.0%	5.0%



Restart



Close

Red Cells

- Hospital
 - ◆ The same
 - ◆ Easy
- Blood Bank,
 - ◆ Production different
 - ◆ Ok if some donors are very flexible

INFORMS 2011



Amsterdam 2013



Sanquin

Publications

- Dijk, N.M. van, R. Haijema, J. van der Wal, C. Smit Sibinga (2009), Blood platelet production: a novel approach for practical optimization, *Transfusion* 49: 411-420
- W. de Kort, M. Janssen, N. Kortbeek, N. Jansen, J. van der Wal and N.M. van Dijk (2011), Platelet pool inventory management: theory meets practice, *Transfusion* 51: 2295-2303.
- Several publications in Operations Research journals

Coefficient of variation (cv) and shelflife

Risk of outdating in %

cv	Shelflife	4	5	6	7
	0.3	10.53	2.76	0.47	0.07
	0.4	13.84	4.92	1.46	0.38
	0.5	20.10	10.01	4.41	1.71
	0.6	24.58	13.81	7.51	3.91
	0.7	30.67	21.46	13.21	7.48

Risk of shortage in %

cv	Shelflife	4	5	6	7
	0.3	1.17	0.34	0.08	0.01
	0.4	1.71	0.71	0.24	0.07
	0.5	2.44	1.33	0.54	0.24
	0.6	3.28	2.28	0.83	0.46
	0.7	4.19	2.64	1.51	0.98