Printing Spare Parts in Remote Locations

By Bram Westerweel, Rob Basten, Jelmar den Boer, Geert-Jan van Houtum

Technische Universiteit
Eindhoven
University of Technology

Where innovation starts

RNLA mission involvement

MINUSMA (Mali)

NLD – MALI: 4000 KM

Supply options (1)

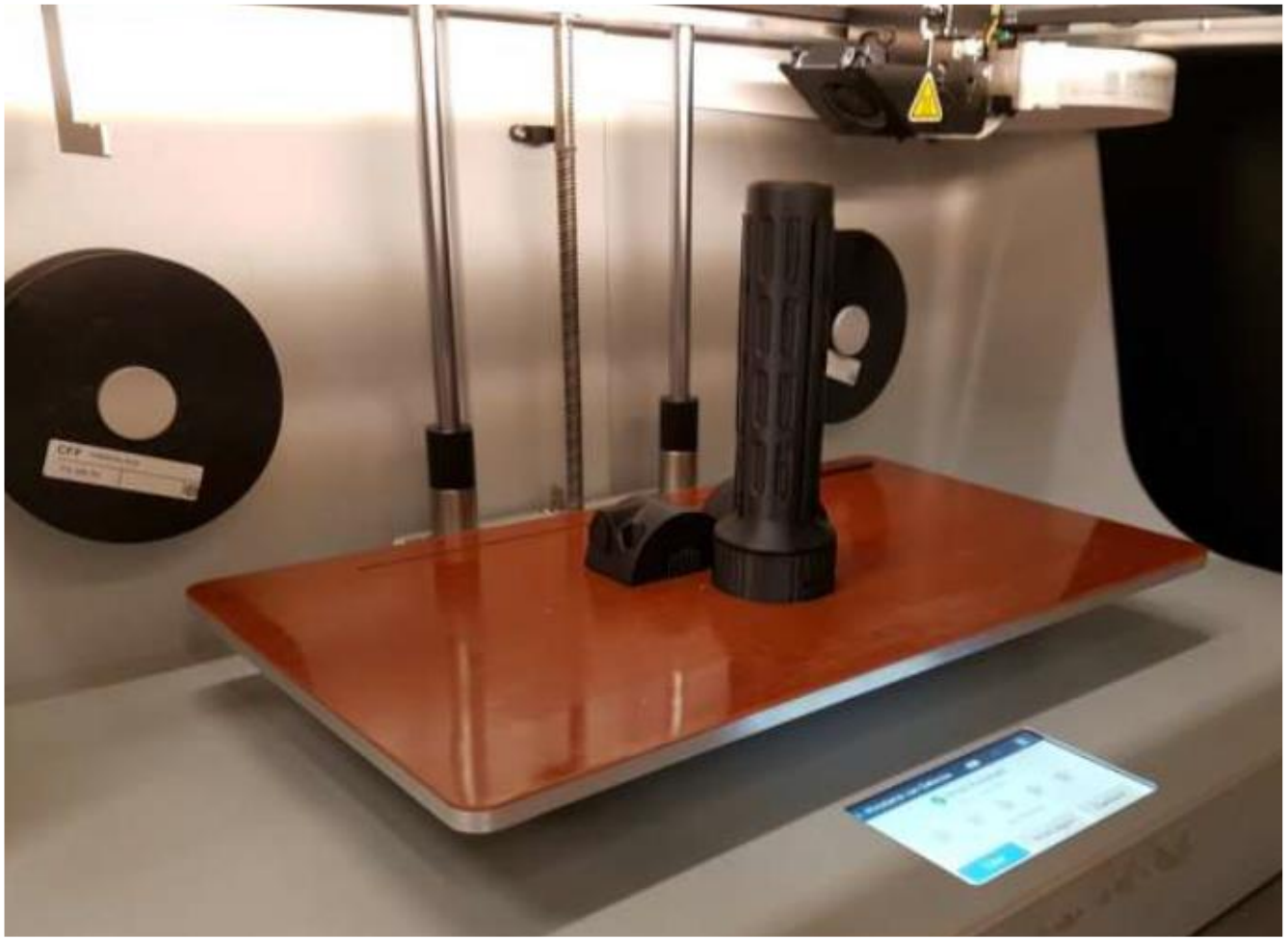
Supply options (2)

Operating bases in remote locations

Forward operations in remote locations

On-site printing results (1)

On-site printing results (2)



On-site printing results (3)

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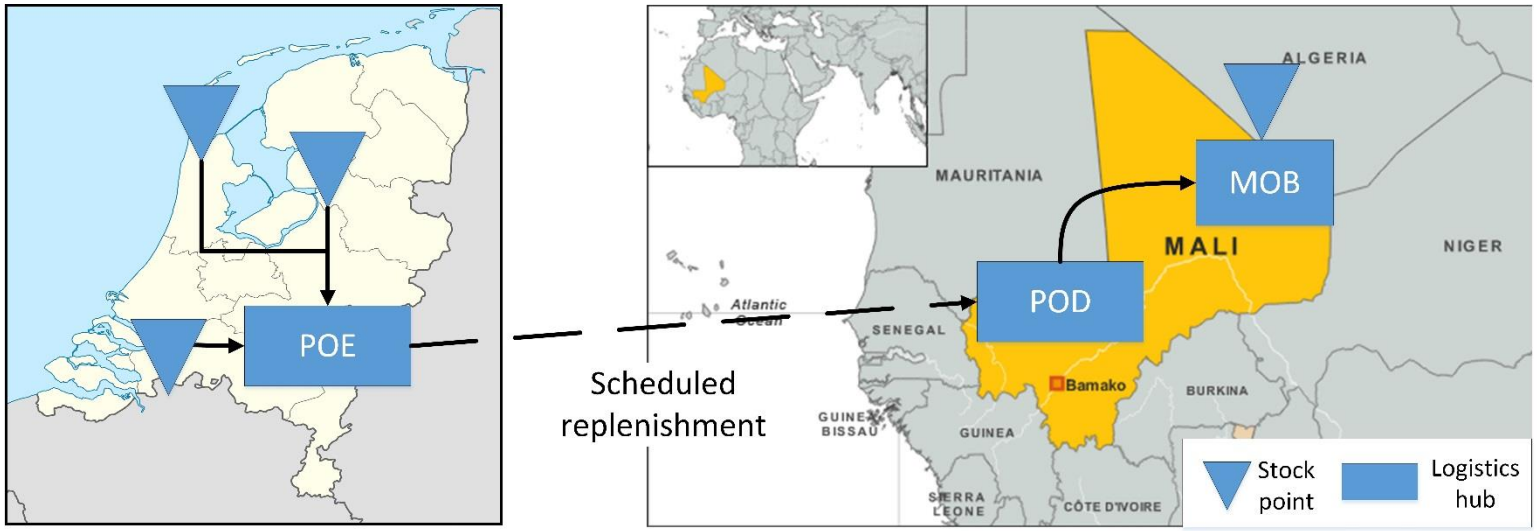
Model building

Supply of spare parts

- Scheduled replenishment to the base every L periods
- On-site printing as an option for backorders that occur in between replenishments



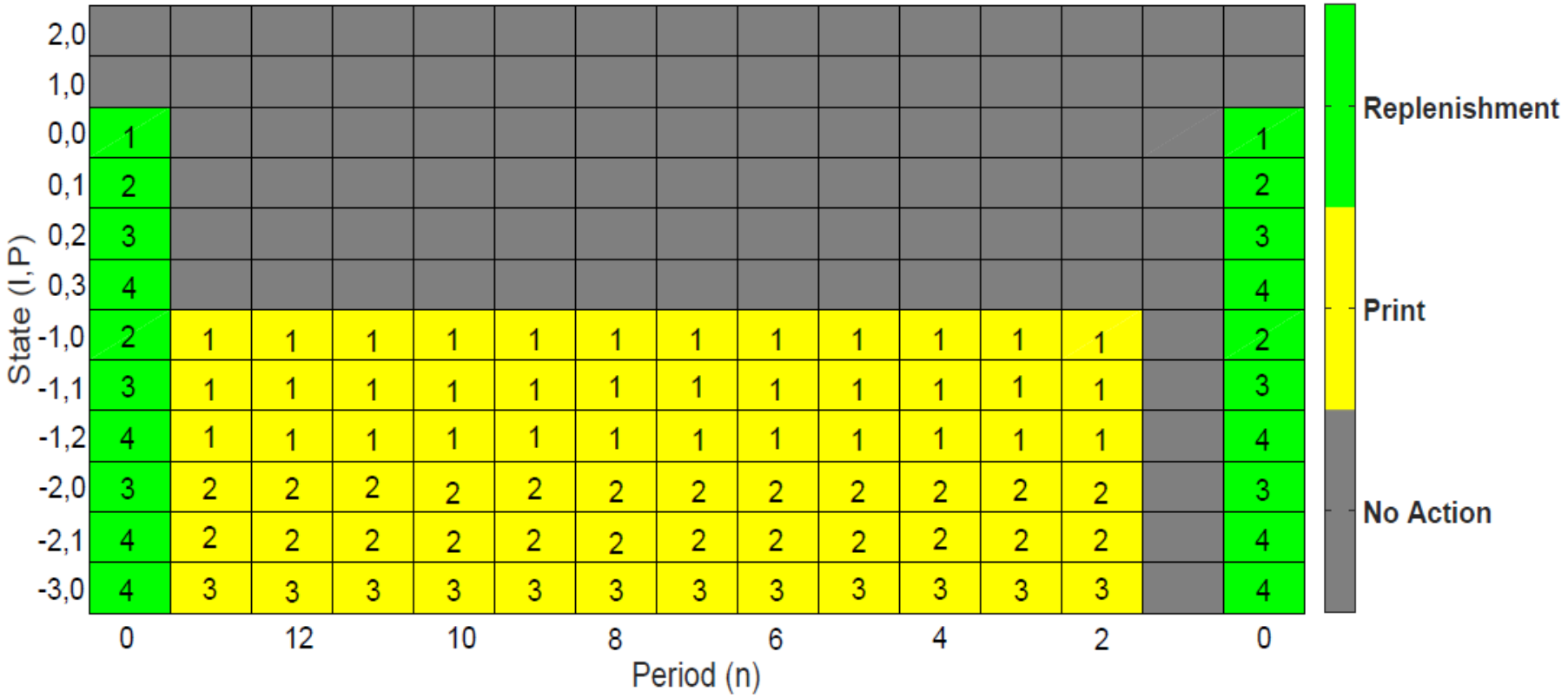
Model building

Spare parts characteristics and demand

- **Replenishment and printing has a zero-period lead time**
- **Printed parts have a higher probability of failure $(p_p > p_r)$**
- **Unit ordering costs c_r and c_p**
- **Number of systems = N**

We assume that printed parts are removed and disposed of at the end of each order cycle

Simple optimal policy structure



p_r	p_p	c_r	c_p	h	b	L	N
0.01	0.2	100	50	1	30	14	3

Model application

The RNLA provides us with data on ~3000 spare parts for three of its systems

Where to start?

Not all parts can be printed and technical assessments are labor intensive

- **Multiple criteria determine printing potential. We use a scoring framework adapted from Knofius et al. (2016)**

	Annual demand	Supplier relation	Purchase cost	Criticality	Score
Part A	Low	Close	High	Critical	0,9
Part B	High	Distant	Low	Non-critical	0,01

- **100 spare parts are assessed by the RNLA's AM expert**
- **14 parts can be printed with the current printer**

Parameterization based on Mali

Printing costs are determined based on volume v, printing speed s, raw material cost c_m, and depreciation cost per hour c_d

$$c_p = \frac{v}{s} c_d + v c_{rm} = v\left(\frac{1.37}{50} + 0.1\right)$$

Printed parts are estimated to fail approximately 10 times faster than regular parts $(p_p = 10p_r)$

Installed base size = $[6, 8, 42]$

Holding costs $h = c_r/365$

Weekly replenishment to the main operating base $(L = 7\ days)$

Application results for Mali

Part rank	Spare part details c_r	c_p	Single-source V_s	S_s	Printing V_p	S_p	Annual savings %	Euro
1	2.62	0.25						
11	235.28	41.28						
50	3.01	0.68						
59	548.61	152.88						
81	186.08	36.95						
264	131.28	49.69						
339	48.40	8.28						
413	10.12	1.80						
554	138.22	26.94						
692	3.21	0.30						
696	2.27	0.39						
830	1.33	5.73						
1018	11.87	8.92						
1386	1.15	0.07						

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Part rank	Spare part details c_r	Spare part details c_p	Single-source V_s	Single-source S_s	Printing V_p	Printing S_p	Annual savings %	Annual savings Euro
1	2.62	0.25	6.82	2	0.85	0	88%	5.97
11	235.28	41.28	339.17	1	143.96	0	58%	195.21
50	3.01	0.68	6.20	2	1.19	0	81%	5.00
59	548.61	152.88	563.86	1	201.35	0	64%	362.51
81	186.08	36.95	275.36	1	97.01	0	65%	178.35
264	131.28	49.69	265.41	2	142.15	1	46%	123.27
339	48.40	8.28	71.53	1	10.84	0	85%	60.69
413	10.12	1.80	20.25	2	3.14	0	84%	17.11
554	138.22	26.94	268.44	2	160.40	1	40%	108.05
692	3.21	0.30	9.71	3	1.90	0	80%	7.80
696	2.27	0.39	5.89	2	2.27	1	62%	3.62
830	1.33	5.73	6.33	5	3.81	3	40%	2.52
1018	11.87	8.92	45.82	4	24.68	2	46%	21.14
1386	1.15	0.07	6.32	6	1.46	1	77%	4.86
							58%	1096.11

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- **Base stock levels decrease by 74% and downtime by 92%**

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- **Base stock levels decrease by 74% and downtime by 92%**
- **We find a -0.52 correlation coefficient between the spare parts rank and annual savings**

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The impact of printing in Mali

To what extent are these parts representative of the entire set?

- **Technical feasibility is not a criterion of the part ranking method**
- **This implies that 10-20% of parts can be printed**
- **And this number will grow as technology develops**

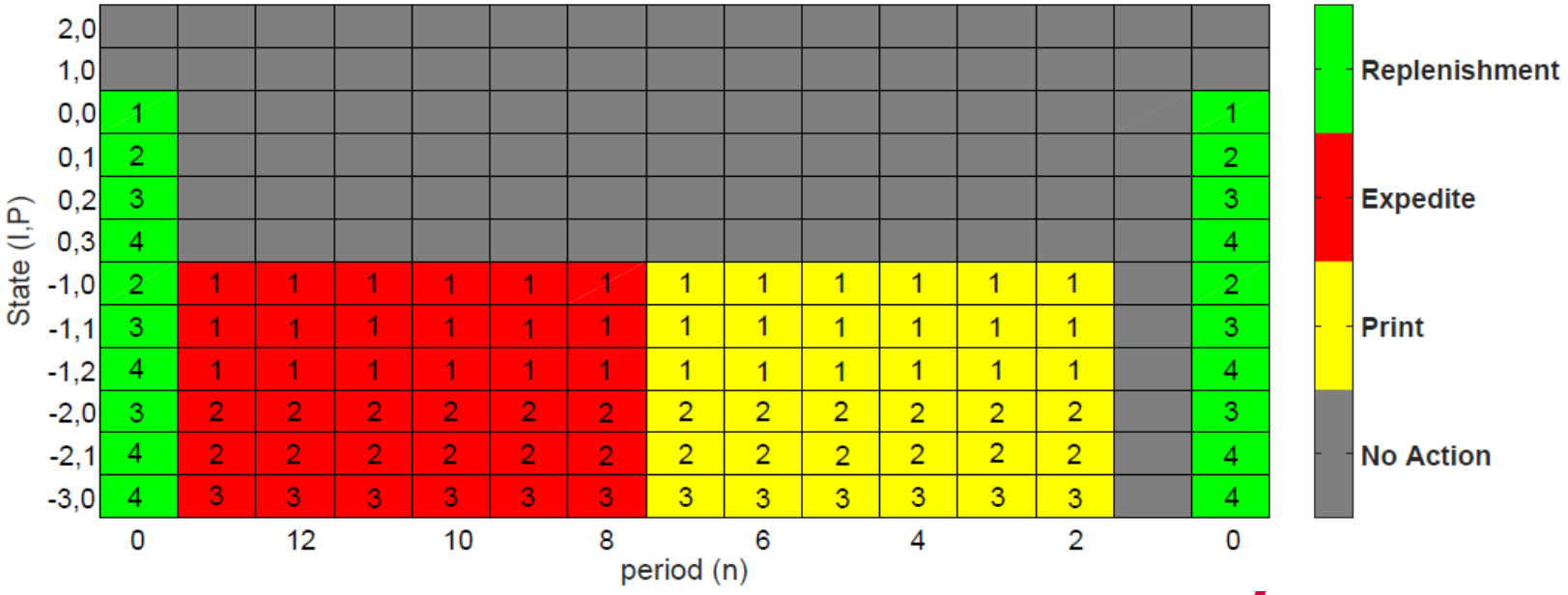
We only considered 3 systems, but there are many more!

Extension: Operations closer to home

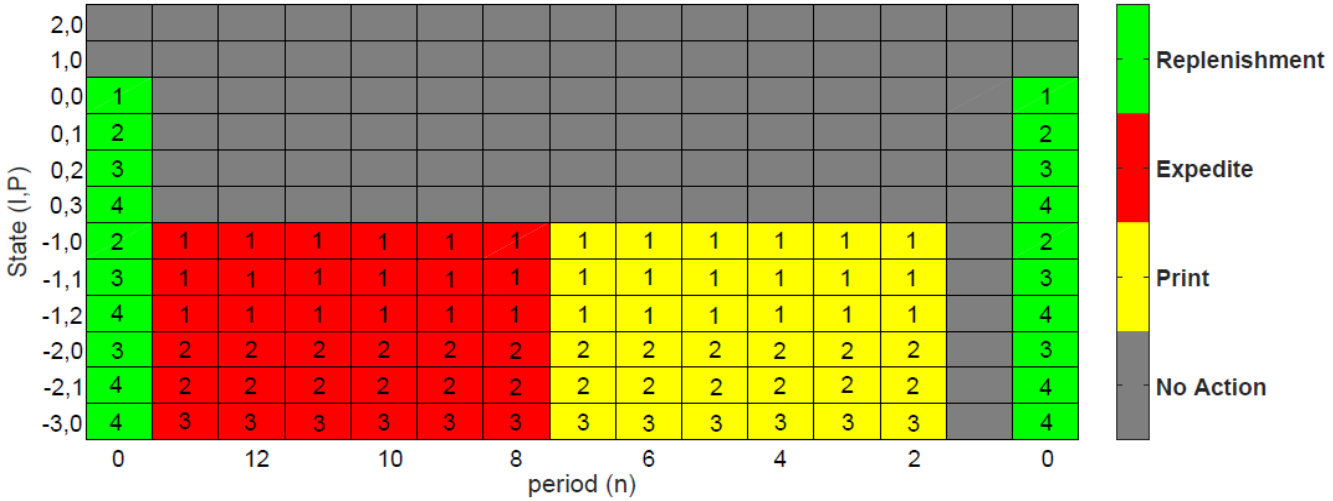
Sometimes parts can be expedited overnight at a premium cost in case of a shortage

- **Denote unit expediting costs by $c_e > c_r$ and $c_e > c_p$**

Illustrating a new optimal policy structure



Extension: Operations closer to home



Suppose that $c_e = 4c_r$ (Recall that printing saves 58% by itself)

- **Expediting saves 9.8% as a stand-alone option**
- **Combining expediting and printing saves 58.7%**

On-site printing will also impact operations closer to the Netherlands and its allies

Conclusions

On-site AM will significantly affect the RNLA's operations in remote locations by:

- **Decreasing required storage space via reduced base-stock levels**
- **Increased asset availability by a cheap temporary solution to inventory shortages**

Benefits are attained even if printed parts have much worse characteristics than regular parts!

On-site AM can be applied to a substantial subset of parts

Broader implications

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