

Reducing Helicopter EMS Cancellations: A Data-Driven Survival Modeling Approach

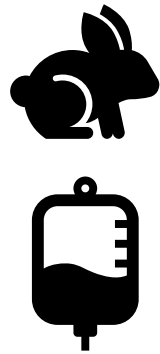
Nina Baumgartner



Introduction



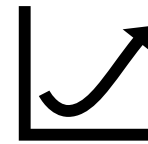
Key part of pre-hospital care



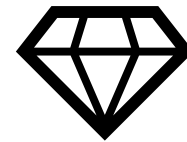
Faster/specialized care



Improve patient outcomes



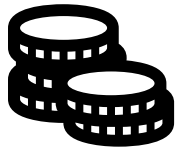
Increase in dispatches



Scarce resource

Motivation

- High cancellation rates
 - Netherlands: 54% [1]
 - UK: 38% [2]
 - Finland: 40% [3]
- Usually by first responder on scene (ambulance)
- Mostly because HEMS not needed (stable, dead, *Scoop and Run*)



[1] Berkeveld, E., Sierkstra, T., Schober, P., Schwarte, L., Terra, M., de Leeuw, M., Bloemers, F., & Giannakopoulos, G. (2021). Characteristics of helicopter emergency medical services (HEMS) dispatch cancellations during a six-year period in a Dutch HEMS region. *BMC Emergency Medicine*, 21(1), 50.

[2] Evans, E. G., Hudson, A., McWhirter, E., & Lyon, R. (2014). A review of the activation triggers and reasons for stand downs of a Helicopter Emergency Medical Service (HEMS). *Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine*, 22(S1), P5

[3] Kurola, J., Wangel, M., Uusaro, A., & Ruokonen, E. (2002). Paramedic helicopter emergency service in rural Finland – do benefits justify the cost? *Acta Anaesthesiologica Scandinavica*, 46(7), 779–784.

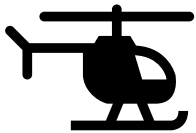
Case study



We experience too many cancellations! And often they happen just after take-off.

- Nijmegen HEMS (*MMT Lifeliner 3*): Pilot, physician, specialized nurse
- Two different triage protocols (NTS, ProQA)
- Dispatch data from 2016-2022
- Focus on specific patient group
 - Fall from height
 - 60% cancellations (of which 87% due to stable patient)
 - 3,000 missions

HEMS Operation



t^n

t^d

t^l

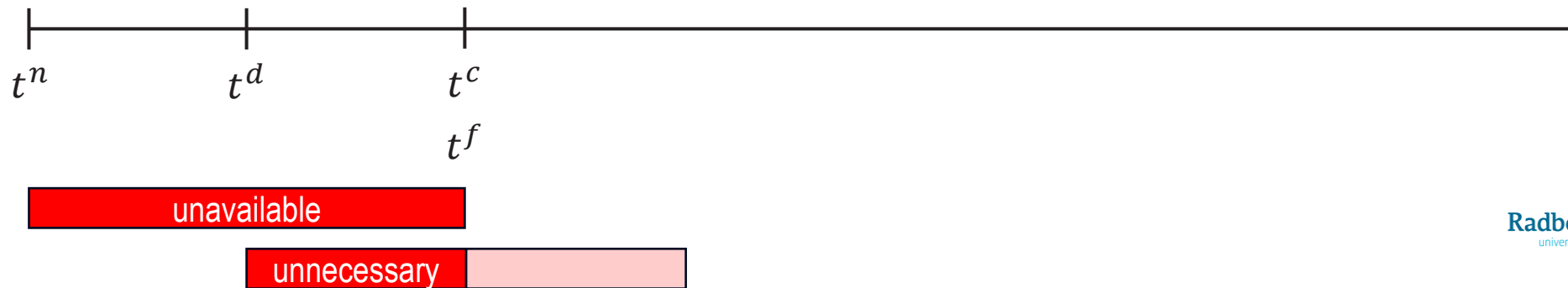
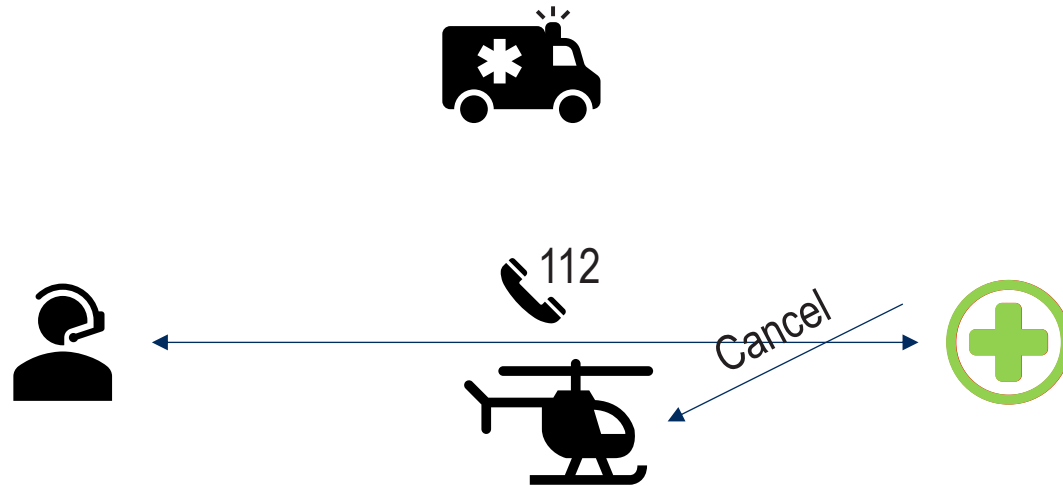
t^a

t^f



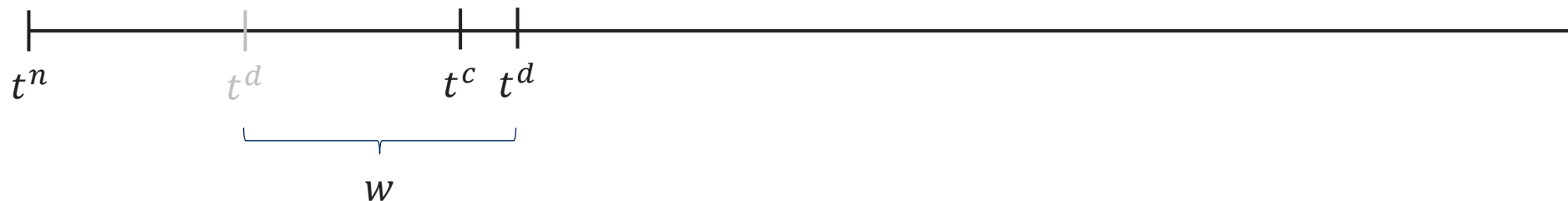
Response time t^r

HEMS Operation: Cancellation

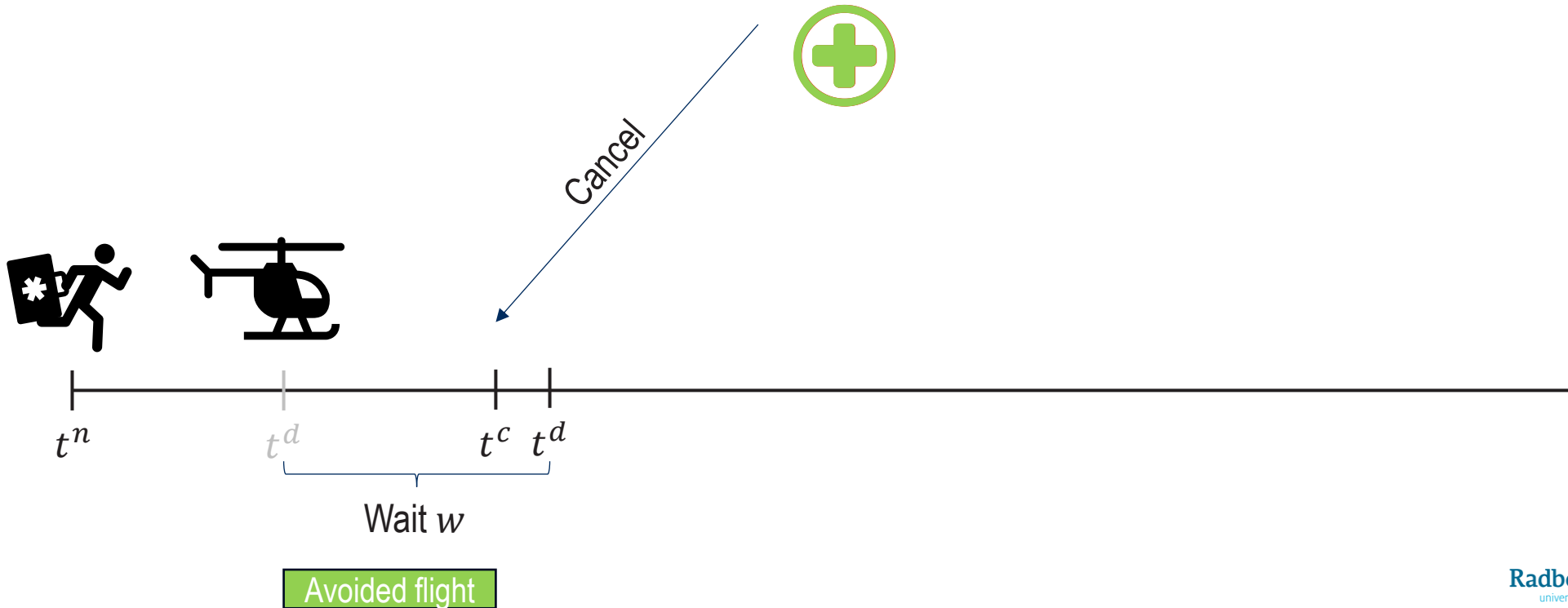


Framework

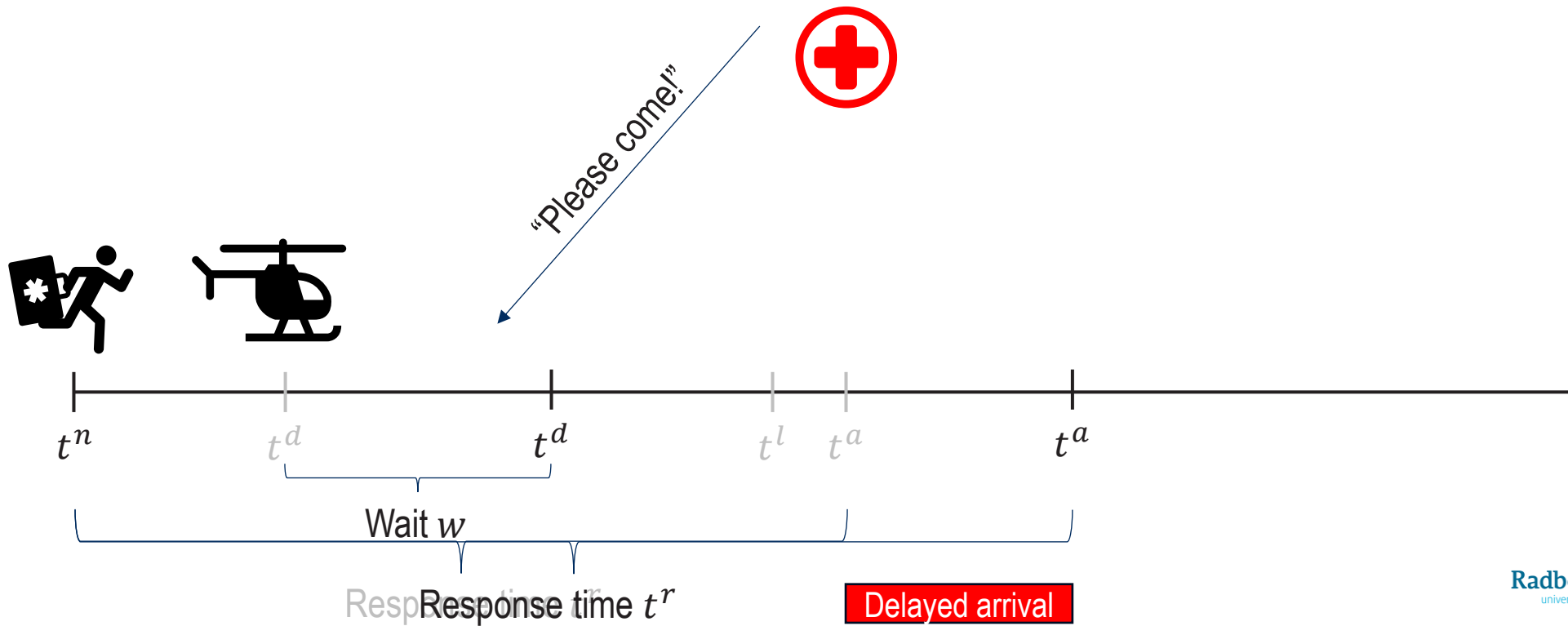
Strategically postpone departure of HEMS



Framework



Framework



Framework

Strategically postpone departure of HEMS



Framework

Strategically postpone departure of HEMS

Cancellation probability model

- Input identification
- Survival modelling
- Impact of postponed departure

Patient outcome model

Pareto optimality analysis

Cancellation rate



Patient outcome

Cancellation probability model

Input identification

Candidate variables X

- Response time
 - Taken from assists
 - Modelled for cancellations
- Age
- Day/night
- Day of the week
- Region
- Dispatch centre
- Dispatch protocol

Univariate logistic regression



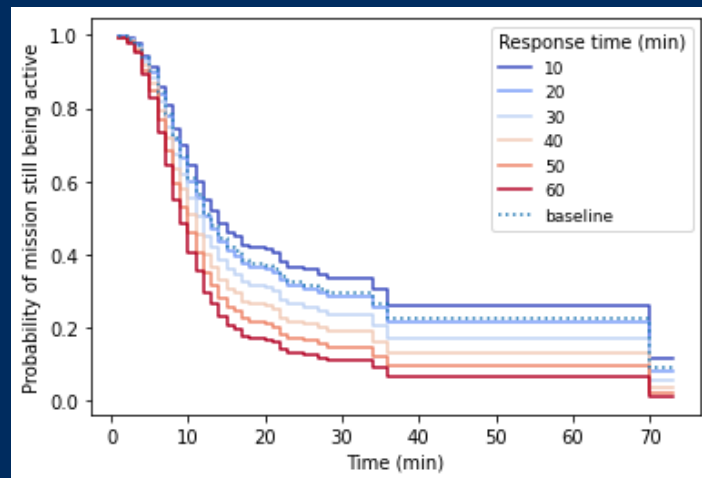
Predictor variables V

- Response time
- Patient type (Child, adult)
- Dispatch protocol (NTS, ProQA)

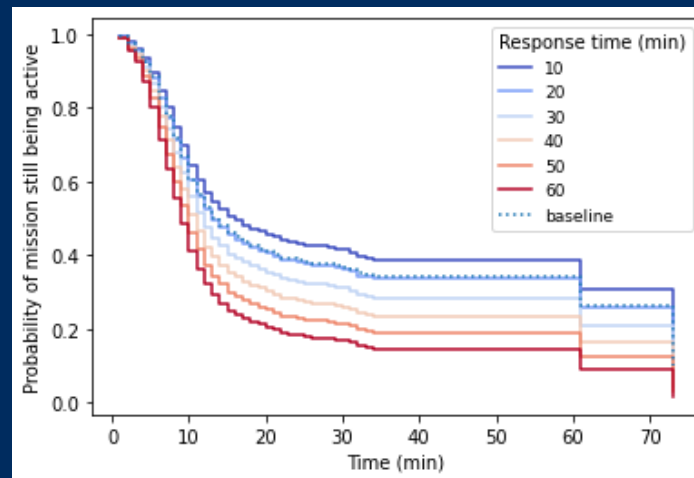
Cancellation probability model

Survival modelling

- Cox Proportional Hazards model
 - Cancelled missions: Time until cancellation known
 - Assisted missions: Time until cancellation censored
- Probability that mission is still active over time
 $s(T^r, V, t)$



Children, NTS



Adults, NTS

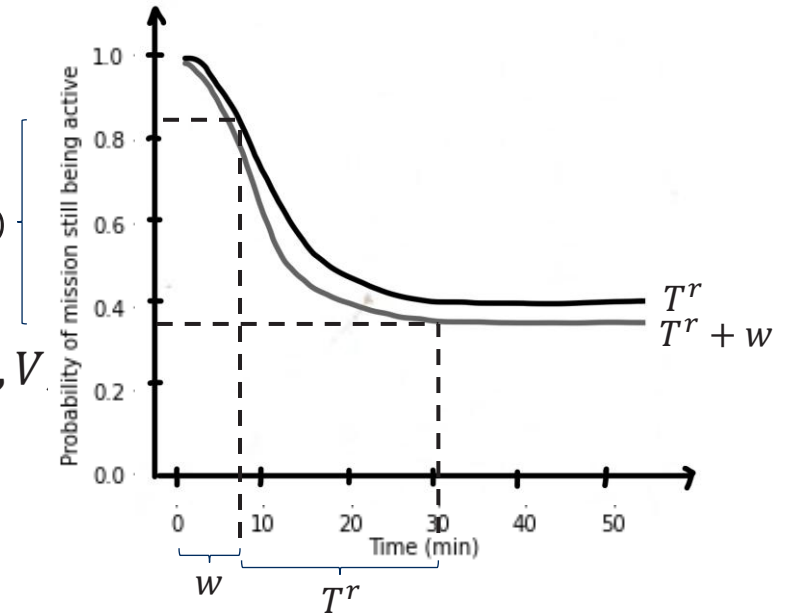
Cancellation probability model

Impact of postponed departure

- Cancellation rate
- Change in cancellation rates

$$c(T^r, V, w) = s(T^r, V, w) - s(T^r + w, V)$$

$$c(T^r, V, w) - c(T^r, V, 0)$$



Change in cancellation rates (%), adults and elderly, NTS.

Wait (min)	Response time (min)					
	6-10	11-15	16-20	21-25	26-30	31-35
0	24.73	46.43	56.63	62.96	67.20	72.37
2	+7.85	+2.74	+0.33	-0.78	-0.92	-1.44
4	+11.96	+1.80	-2.14	-4.11	-4.34	-6.39
6	+9.58	-4.26	-9.55	-12.62	-13.14	-16.83
8	+3.98	-12.00	-18.90	-22.33	-24.01	-28.63
10	-2.90	-20.27	-28.32	-31.32	-34.96	-40.04

Framework

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Cancellation probability model

Patient outcome model

- Case distinction
- Morbidity model
- Impact of postponed departure

Pareto optimality analysis

Cancellation rate



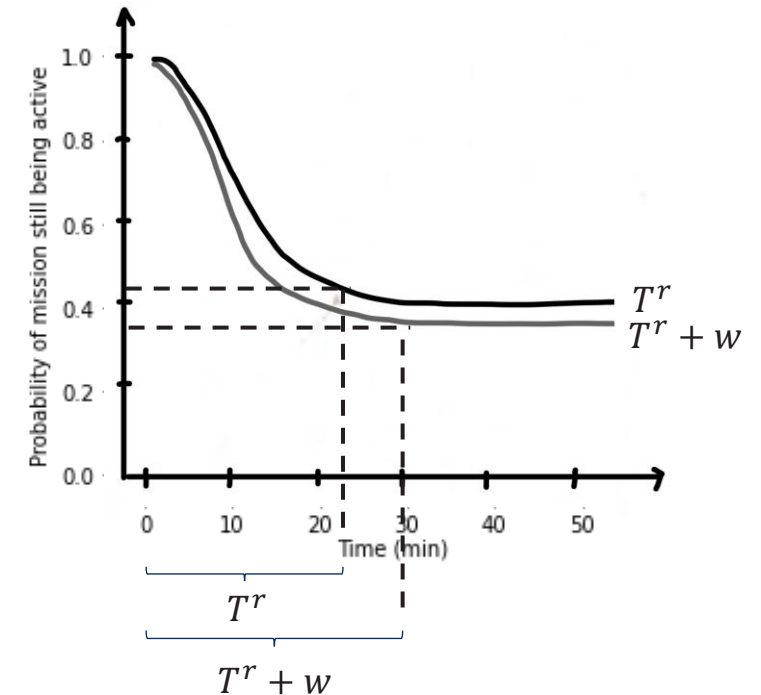
Patient outcome

Patient outcome model

Case distinction

- ① Mission is cancelled before earliest possible HEMS arrival
- ② HEMS would have assisted patient if departed immediately, but is cancelled due to delay
- ③ Delayed HEMS treatment due to postponed departure

Probability of ② or ③ : $s(T^r, V, T^r)$

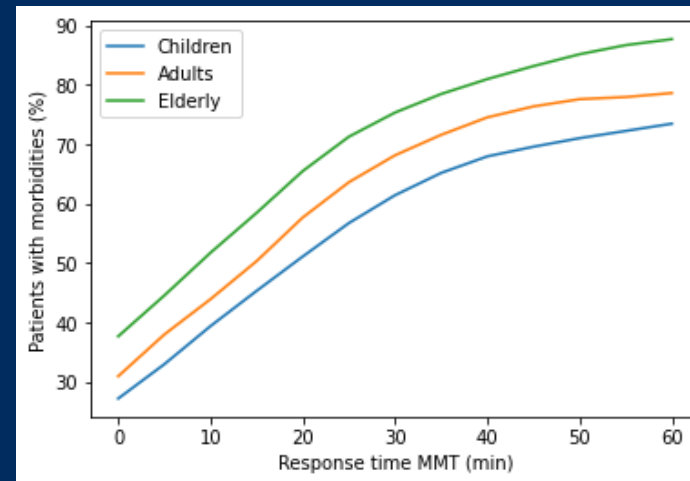


Patient outcome model

Morbidity model

- Further group patients by characteristics U and injury types I
- Probability that patient with characteristics U, V suffers injury type $i \in I$
 $P(U, V, i)$
- Probability that patient with characteristics U , injury type I , develops morbidities with HEMS response time t
 $mor(U, I, t)$

- U and I defined by experts
- $P(U, V, I)$ determined on historical data
- $mor(U, I, t)$ defined by expert study



Neurotrauma and additional respiratory/circulatory problem

Patient outcome model

Impact of postponed departure

- Expected morbidity

$$m(T^r, U, V, w) = s(T^r, V, T^r) \sum_{i \in I} P(U, V, i) \cdot mor(U, i, T^r + w)$$

- Change in expected morbidity

$$m(T^r, U, V, T^r + w) - m(T^r, U, V, T^r)$$

Increase in morbidity (%), primary dispatch, adults, NTS.

		Response time (min)					
		6-10	11-15	16-20	21-25	26-30	31-35
Wait (min)	0	30.45	34.75	39.21	43.22	46.27	48.63
	2	+1.32	+0.93	+0.75	+0.49	+0.33	+0.23
	4	+2.61	+1.89	+1.43	+0.93	+0.64	+0.44
	6	+3.89	+2.86	+2.04	+1.33	+0.91	+0.63
	8	+5.21	+3.75	+2.59	+1.69	+1.17	+0.79
	10	+6.59	+4.54	+3.07	+2.01	+1.41	+0.93

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Strategically postpone departure of HEMS



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Patient outcome

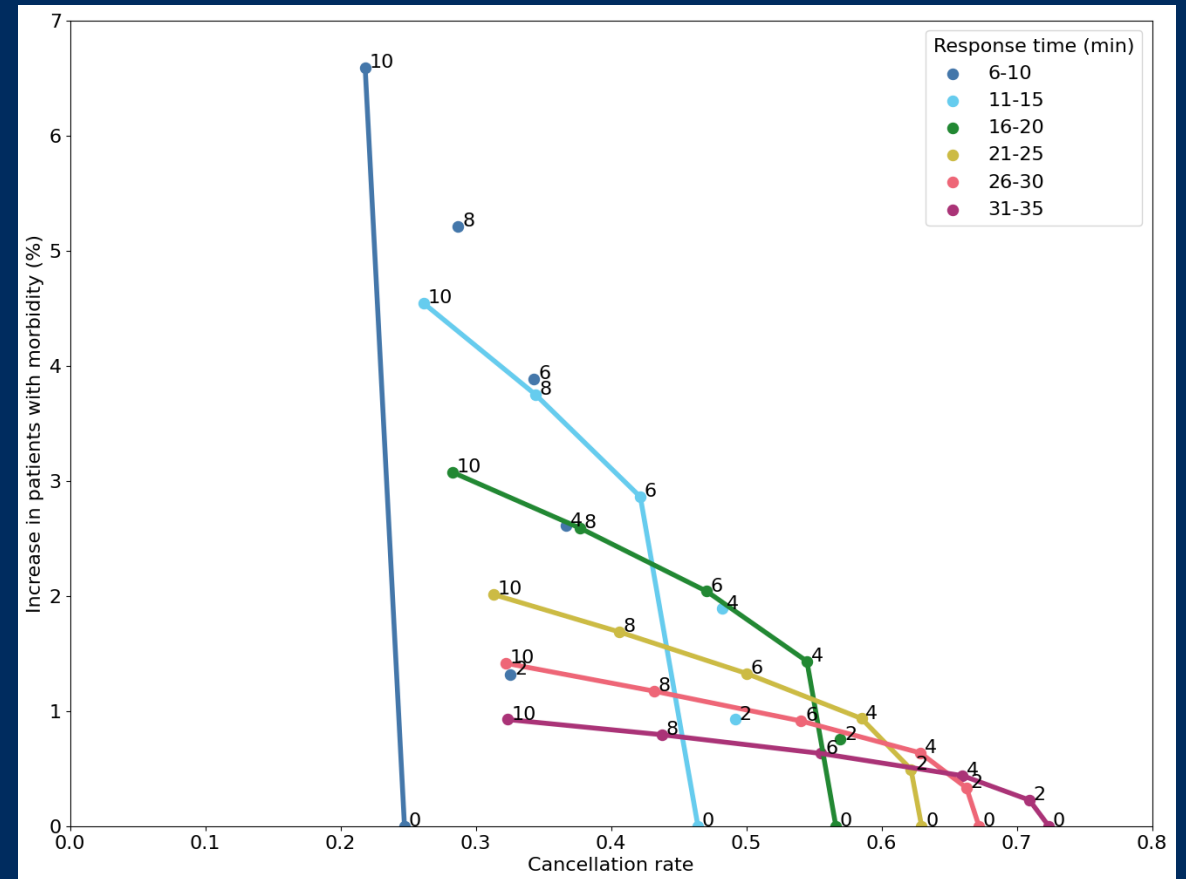
Pareto optimality analysis

Cancellation rate  Patient outcome

- Determining “right” balance outside scope
- E.g., Cost-effectiveness, ethical considerations
- Pareto-optimal: No other feasible solution improves one objective without deteriorating the other

- Flat frontiers favour postponement
- Steep frontiers come with little potential and high risk
- Switching point?

- Asymmetry between rate of cancellation reduction and rate of morbidity increase
- Favours long postponements



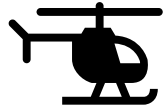
Adults, NTS

Discussion

- Integration
 - Consider recommendation as maximum *acceptable* waiting time
 - Use to gather information
 - May pave way to novel triage system accounting for likelihood of HEMS need
- Improving accuracy
 - Ambulance data (response time)
 - Proximity of patient to hospital/trauma centre
- Model advises against postponement for short response times (?)
 - Assist/cancellation is flawed proxy for HEMS need
 - HEMS Benefit Score [4]

Summary

- Developed framework to balance HEMS cancellations with patient outcomes
- First to use data-driven survival analysis to model HEMS cancellation probability over time
- Pareto optimal trade-offs demonstrate sharp cancellation reduction with minimal morbidity impact
 - Cancellations -40%; Morbidity +1%
- Adaptable to various HEMS systems
- Foundation for enhancing efficiency, availability and reducing system-wide costs



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