Evaluating Heterogeneous Ambulance Fleet Allocations in Jakarta

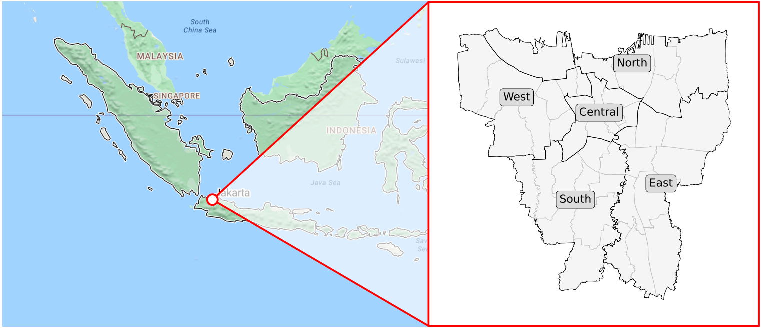
Geraint Palmer, Mark Tuson, Sarie Brice, Paul Harper, Vincent Knight, Leanne Smith, and Daniel Gartner

www.geraintianpalmer.org.uk
@GeraintPalmer

ORAHS, Graz 2023

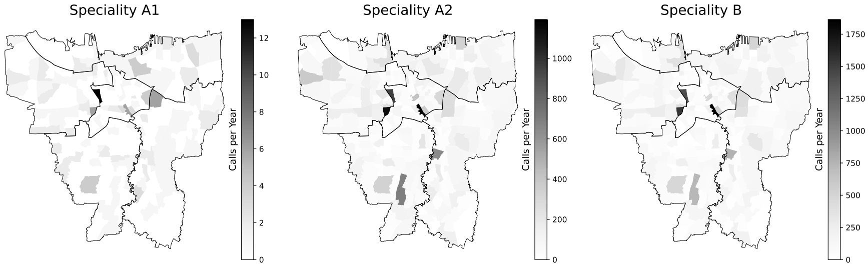
Jakarta, Indonesia

Jakarta, Indonesia



Jakarta, Indonesia

The Problem

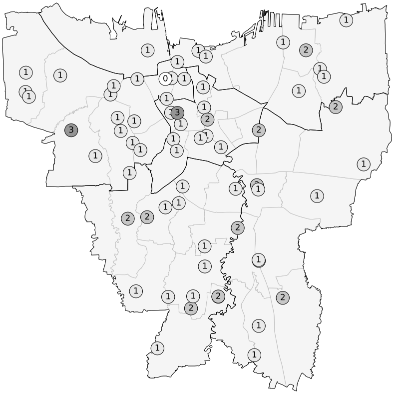

Speciality A1
Speciality A2
Speciality B
Calls per Year
0
2
4
6
8
10
12
0
200
400
600
800
1000
0
250
500
750
1000
1250
1500
1750

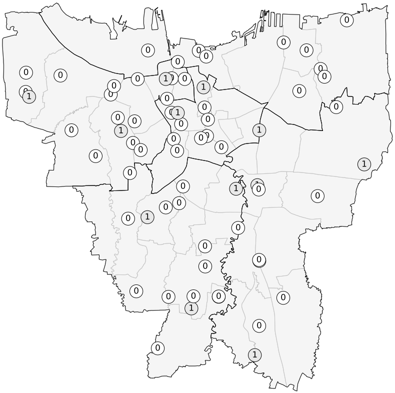
The Problem

Primary Vehicle
Emergency Ambulance (EA)

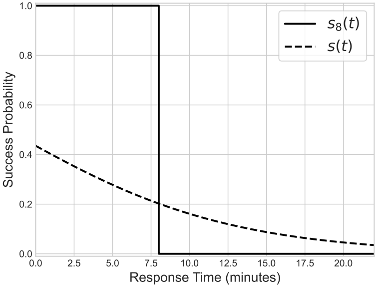
Secondary Vehicle
Rapid Response Vehicle (RRV)

The Problem





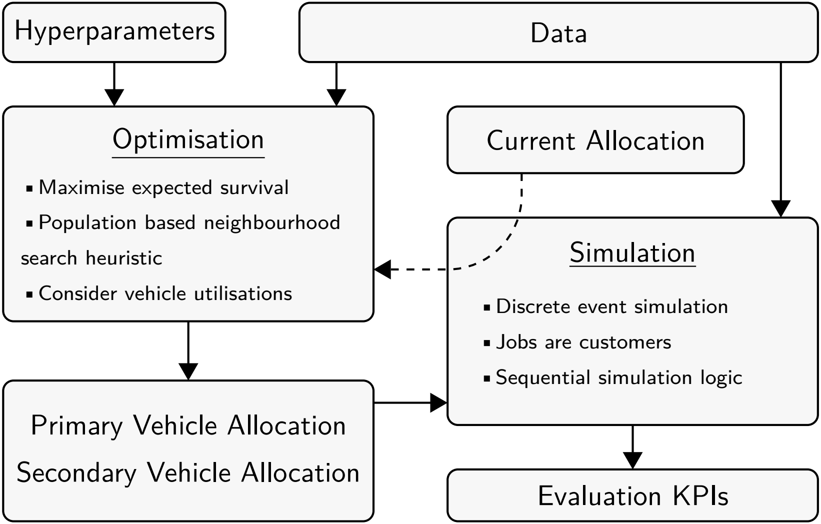
Survival Functions



$$s(t) = \left(1 + e^{0.26+0.139t}\right)^{-1}$$

$$s_L(t) = \begin{cases} 1 \text{ if } 0 \leq t \leq L \\ 0 \text{ if } t > L \end{cases}$$

Plan: Optimisation & Simulation



MESLMHPHF

Number of patients of a speciality in $\mathcal{K}_A$ surviving

Number of patients of a speciality in $\mathcal{K}_B$ surviving

$$g\left(Z_a, \tilde{Z}_a\right) = \sum_{p \in \mathcal{P}} \sum_{a \in \mathcal{A}} \left(\sum_{k \in \mathcal{K}_A} w_k \ \lambda_{pk} \hat{\Psi}_{kpa} + \sum_{k \in \mathcal{K}_B} w_k \ \lambda_{pk} \Psi_{kpa} \right)$$

Expected number of patients surviving, given allocations Z_a and $\tilde{Z}_a$

Weights

Probability of surviving

Probability of that a *primary* vehicle is not busy

Probability of patient speciality k at location p being seen by a *primary* vehicle from station a and survivng

Probability all closer *primary* vehicles are busy

$$\Psi_{kpa} = s_k\left(t_{pa}\right) \left(1 - \pi_a^{Z_a}\right) \prod_{\alpha \in \mathcal{A}} \pi_\alpha^{\left(Z_\alpha \beta_{p\alpha a}\right)}$$

Probability of surviving

Probability of that a *secondary* vehicle is not busy

Probability all closer *secondary* vehicles are busy

Probability of patient speciality k at location p being seen by a vehicle from station a and survivng

Probability all closer *primary* vehicles are busy

$$\hat{\Psi}_{kpa} = s_k\left(\hat{t}_{pa}\right) \left(1-\tilde{\pi}_a^{\tilde{Z}_a}\right) \prod_{\alpha\in\mathcal{A}} \tilde{\pi}_\alpha^{\left(\tilde{Z}_\alpha \beta_{p\alpha a}\right)} \pi_\alpha^{(Z_\alpha R_{p\alpha a})}$$

$$+ s_k\left(t_{pa}\right) \left(1-\pi_a^{Z_a}\right) \prod_{\alpha\in\mathcal{A}} \pi_\alpha^{(Z_\alpha \beta_{p\alpha a})} \tilde{\pi}_\alpha^{\left(\tilde{Z}_\alpha (1-R_{pa\alpha})\right)}$$

Probability all closer *secondary* vehicles are busy

Probability all closer *primary* vehicles are busy

Probability of that a *primary* vehicle is not busy

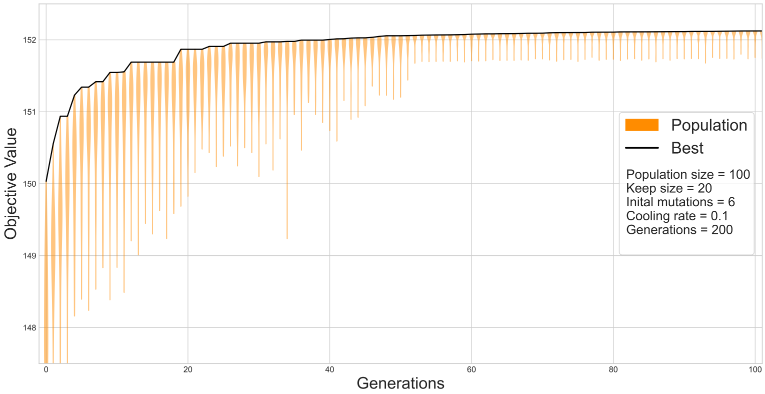
Probability of surviving

Utilisations

$$\lambda_a = \sum_{p\in\mathscr{P}} \sum_{k\in\mathscr{K}} \lambda_{pk} \left(1 - \left(\frac{\lambda_a}{\mu}\right)^{Z_a}\right) \prod_{\alpha\in\mathscr{A}} \left(\frac{\lambda_\alpha}{\mu}\right)^{\left(Z_\alpha \beta_{p\alpha a}\right)}$$

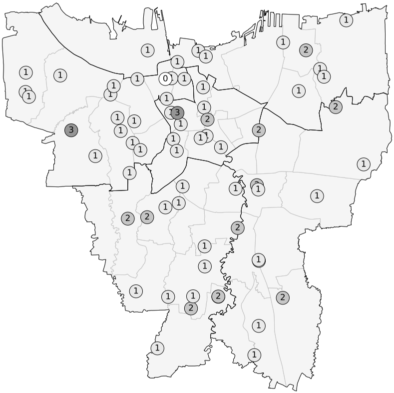
$$\tilde{\lambda}_a = \sum_{p\in\mathscr{P}} \sum_{k\in\mathscr{K}_A} \lambda_{pk} \left(1 - \left(\frac{\tilde{\lambda}_a}{\tilde{\mu}}\right)^{\tilde{Z}_a}\right) \prod_{\alpha\in\mathscr{A}} \pi_\alpha^{\left(Z_\alpha R_{p\alpha a}\right)} \left(\frac{\tilde{\lambda}_\alpha}{\tilde{\mu}}\right)^{\left(\tilde{Z}_\alpha \beta_{p\alpha a}\right)}$$

Heuristic

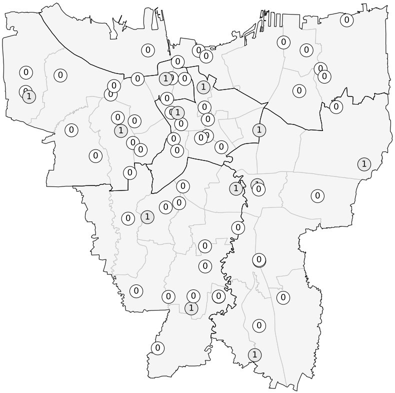

Population
Best
Population size = 100
Keep size = 20
Inital mutations = 6
Cooling rate = 0.1
Generations = 200
Objective Value
Generations
152
151
150
149
148
0
20
40
60
80
100

Optimised Allocation

EA Allocation



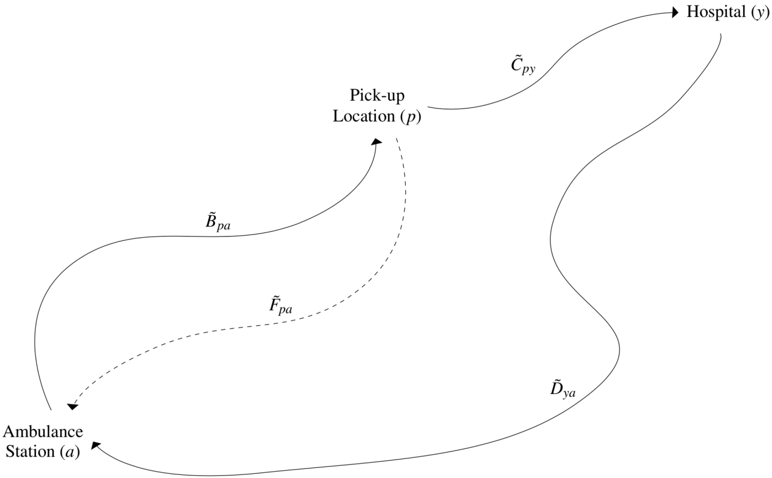
RRV Allocation



Simulation

- Customers are ambulance jobs
- Ambulances are servers
- Jobs routed to closest ambulance
- Sequential logic for secondary vehicles

Simulated Routes



Current vs Optimised

Allocation	Baseline	Improved
Ambulance Utilisation	28.30%	28.37%
RRV Utilisation	20.43%	16.67%
Mean Response Time (mins)	17.67	17.83
Percent Abandoned	0%	0%
Expected Survival	98.34%	99.75%

Summary & Future Work

- MESLMHPHF objective function
- Considers utilisations
- Simulation model

- Consider demand scenarios
- Consider vehicle numbers

- Location dependent μ's
- Replicate work with Welsh Ambulance Trust

Evaluating Heterogeneous Ambulance Fleet Allocations in Jakarta

Geraint Palmer, Mark Tuson, Sarie Brice, Paul Harper, Vincent Knight, Leanne Smith, and Daniel Gartner

www.geraintianpalmer.org.uk
@GeraintPalmer

ORAHS, Graz 2023