

The School of Mathematics



THE UNIVERSITY  
*of* EDINBURGH

# Antimicrobial Resistance Title

by

Ravi Patel, S1889112

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Supervised by  
INSERT NAME HERE

## Acknowledgments

Thanks to my (...), and also to my best friend (...), and also to the fact I have no friends! Lol XD BANTER.

## Own Work Declaration

This is my own work, except the people I referenced. But I referenced them so it's FINE.

## Executive summary

**Note:** Should I include an overview of each section here?

Here I will write a very good, precise and brief executive summary.

# **1 Introduction**

Here I will write a very good, precise and brief introduction. Particularly, Section 2 is good!

## 2 Background

## 3 Test section

In the following, I explain some background stuff. I should really cut this short, but  
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But I can also end a line with a double backslash.

### 3.1 Models

Models are *very* helpful because.

- They're good.
- They're helpful.

## 3.2 Techniques

Techniques even better because.

1. They're magnificent.
2. If they work.

## 4 Technical Stuff

Now it's getting very technical ... I will cite Shiina & Birge (2004), Gröwe-Kuska & Römisch (2001). I will also show my incredible  $\alpha$ ,  $\beta$  and  $\gamma$  mathematics and do some other fancy stuff.

### 4.1 Formulae

For example look at this

$$\min \sum_{s \in \mathcal{S}} Pr_s \left[ \sum_{t=1}^T \left( \sum_{g \in \mathcal{G}} \left( \alpha_{gts} C_g^0 + p_{gts} C_g^1 + (p_{gts})^2 C_g^2 \right) + \sum_{g \in \mathcal{C}} \gamma_{gts} C_g^s \right) \right], \quad (4.1)$$

and you will see that it has a little number on the side so that I can refer to it as equation (4.1). Now if I do this

$$\begin{aligned} \sum_{i=1}^n k_i &= 20 \\ \sum_{j=20}^m \delta_i &\geq \eta \end{aligned} \quad (4.2)$$

I can align two formulae and control which one has a number on the side. It is (4.2). I can also do something like this

$$Y_l = \begin{bmatrix} \left( y_s + i \frac{b_c}{2} \right) \frac{1}{\tau^2} & -y_s \frac{1}{\tau e^{-i\theta s}} \\ -y_s \frac{1}{\tau e^{i\theta s}} & y_s + i \frac{b_c}{2} \end{bmatrix},$$

and it won't have a number on the side. Now if I have to do some huge mathematics I'd better structure it a little and include linebreaks etc. so that it fits on one page.

$$\begin{aligned} p_l^f &= G_{l11} \left( 2v_{F(l)} \bar{v}_{F(l)} - \bar{v}_{F(l)}^2 \right) \\ &+ \bar{v}_{F(l)} \bar{v}_{T(l)} \left[ B_{l12} \sin(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) + G_{l12} \cos(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) \right] \\ &+ \begin{bmatrix} \bar{v}_{T(l)} \left[ B_{l12} \sin(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) + G_{l12} \cos(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) \right] \\ \bar{v}_{F(l)} \left[ B_{l12} \sin(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) + G_{l12} \cos(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) \right] \\ \bar{v}_{F(l)} \bar{v}_{T(l)} \left[ B_{l12} \cos(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) - G_{l12} \sin(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) \right] \\ \bar{v}_{F(l)} \bar{v}_{T(l)} \left[ -B_{l12} \cos(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) + G_{l12} \sin(\bar{\delta}_{F(l)} - \bar{\delta}_{T(l)}) \right] \end{bmatrix} \cdot \begin{bmatrix} v_{F(l)} - \bar{v}_{F(l)} \\ v_{T(l)} - \bar{v}_{T(l)} \\ \delta_{F(l)} - \bar{\delta}_{F(l)} \\ \delta_{T(l)} - \bar{\delta}_{T(l)} \end{bmatrix}, \end{aligned} \quad (4.3)$$

This is a lot of fun!



## 4.2 Important Things

Finally we should have a nice picture like this one. However, I won't forget that figures and table are environments which float around in my document. So LaTeX will place them wherever it thinks they fit well with the surrounding text. I can try to change that with a float specifier, e.g. [!ht]. Now I want to use one of my own environments. I want to define

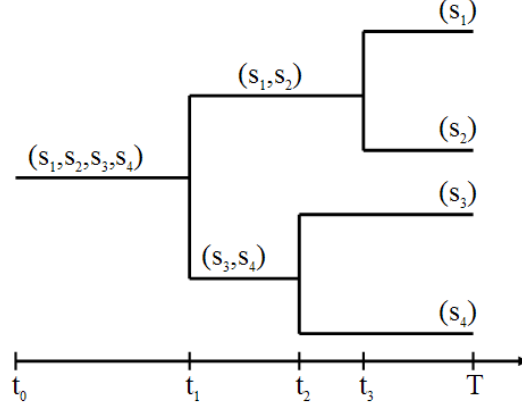


Figure 1: Look at this scenario tree with funny times  $t_1$  and scenarios  $s_1$  etc.

something.

**Definition 4.1** *I define*

$$\Gamma_\eta := \sum_{i=1}^n \sum_{j=i}^n \xi(i, j)$$

I definitely need some good tables, so I do this. I should really refer to Table 1.

Case	Generators	Therm. Units	Lines	Peak load: [MW]	[MVar]
6 bus	3 at 3 buses	2	11	210	210
9 bus	3 at 3 buses	3	9	315	115
24 bus	33 at 11 buses	26	38	2850	580
30 bus	6 at 6 buses	5	41	189.2	107.2
39 bus	10 at 10 buses	7	46	6254.2	1387.1
57 bus	7 at 7 buses	7	80	1250.8	336.4

Table 1: Something that doesn't make sense.

## 4.3 And now something else

Let:

$$\begin{aligned}
\Omega_0 &= \{(x, y, z, f) : \text{satisfying (9) -- (19)}\}, \\
\Omega_1 &= \{(x, y, z, f) : \text{satisfying (9), (11) -- (20)}\}, \\
\bar{\Omega}_0 &= \{\mathbf{0} \leq (x, y, z, f) \leq \mathbf{1} : \text{satisfying (9) -- (18)}\}, \\
\bar{\Omega}_1 &= \{\mathbf{0} \leq (x, y, z, f) \leq \mathbf{1} : \text{satisfying (9), (11) -- (18), (20)}\}.
\end{aligned}$$

where  $\mathbf{0}$  and  $\mathbf{1}$  are vectors of appropriate dimensions with 0's and 1's, respectively. Next we see that both  $\Omega_0$  and  $\Omega_1$  give equivalent formulations for the A-MSSP. In particular, the following statements hold:

**Proposition 1**  $\Omega_0 \subseteq \Omega_1$ .

**Proof.** Let us suppose there exists  $(x, y, z, f) \in \Omega_1$  such that  $(x, y, z, f) \notin \Omega_0$ . Then, there exist indices  $i \in I$  and  $t \in \{0, \dots, |T| - s_i\}$  with  $x_i^t > 0.5 \left( \sum_{h=1}^{s_i} x_i^{t+h} + 1 \right)$ . By definition,  $x_i^t = 1$  and  $x_i^{t+h} = 0$  for all  $h \in \{1, \dots, s_i\}$ . By (11) and (12),  $\sum_{h=1}^{s_i} f_i^{th} = 1$ , so  $f_i^{th'} = 1$  for some  $h' \in \{1, \dots, s_i\}$ . But then,

$$0 = x_i^{t+h'} = \sum_{h=\max\{1, t+h'-(|T|-s_i)\}}^{\min\{s_i, t+h'\}} f_i^{t+h'-h, h} \geq f_i^{th'} = 1,$$

as  $h' \in [\max\{1, t + h' - (|T| - s_i)\}, \min\{s_i, t + h'\}]$ . □

This immediately gives us

**Corollary 1** *AS is a valid formulation for the A-MSSP.*

Next we compare the Linear Programming (LP) relaxations of the two formulations.

**Proposition 2**  $\bar{\Omega}_1 \subseteq \bar{\Omega}_0$ .

**Proof.** Homework □

## 5 Conclusions

I have no idea how to conclude, so I don't write much. But the stuff that follows is important.

## References

- Gröwe-Kuska, N. & Römisch, W. (2001), *Stochastic unit commitment in hydro-thermal power production planning*, Preprints aus dem Institut für Mathematik, Humboldt-Universität zu Berlin, Institut für Mathematik.
- Shiina, T. & Birge, J. R. (2004), ‘Stochastic unit commitment problem’, *International Transactions in Operational Research* **11**(1), 19–32.

## Appendices

### A An Appendix

Some stuff.

## **B   Another Appendix**

Some other stuff.