Applied Optimisation
- What Practice Teaches

r esent ed by: **i r u r t h a n a r i**
. epar t ment of . .

OptALI Optimisation in Industry
Workshop, 24-26 February, 2014,
Auckland, New Zealand

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Plan of the Talk

- Introduction
- Applied Optimisation – My Industrial Experience
- Better than the optimum?
- Going to the moon easy - crossing the road difficult
- ESP – not the extrasensory one
- False fire alarm- method in madness
- Don’t ignore remarks- analyse
- Concluding remarks

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Learning
is finding out
what you already know.
Doing is demonstrating that
you know it.
teaching is reminding others
that they know
just well as you.
You are all learners,
Doers,
Teachers.

– *Richard Bach*

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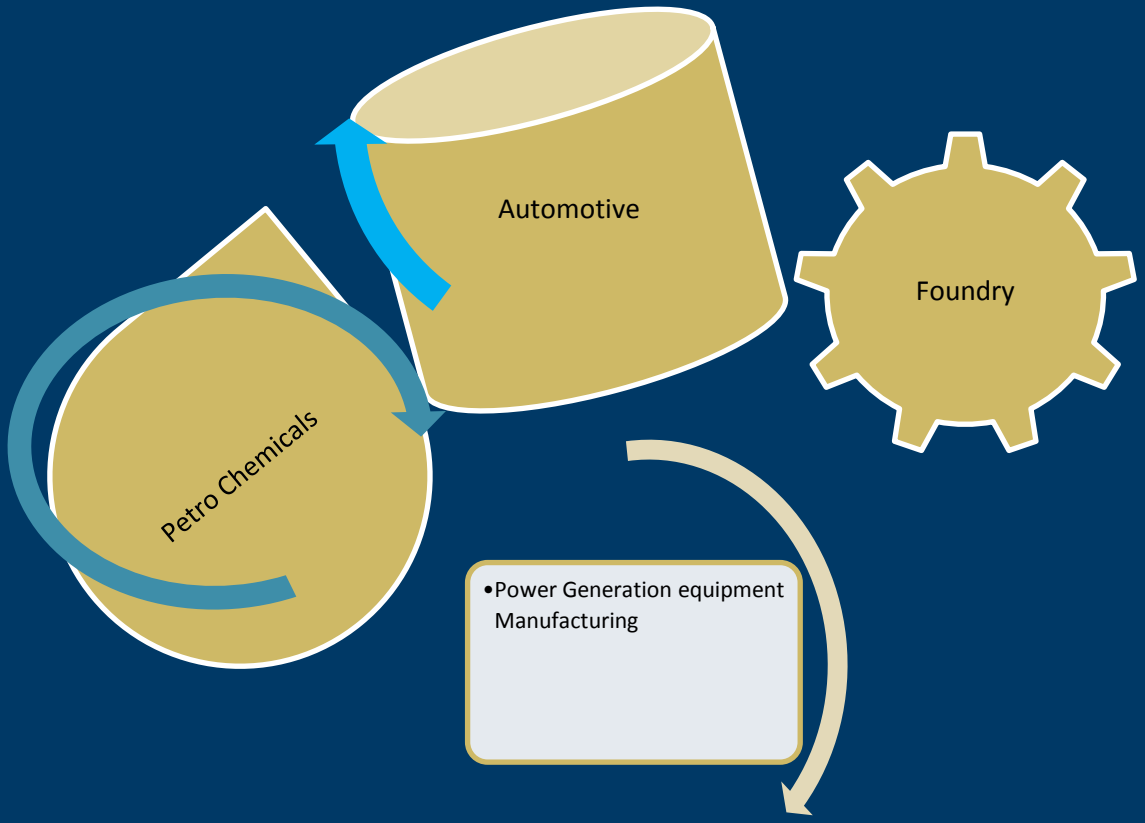
Applied Optimisation – My Industrial Experience



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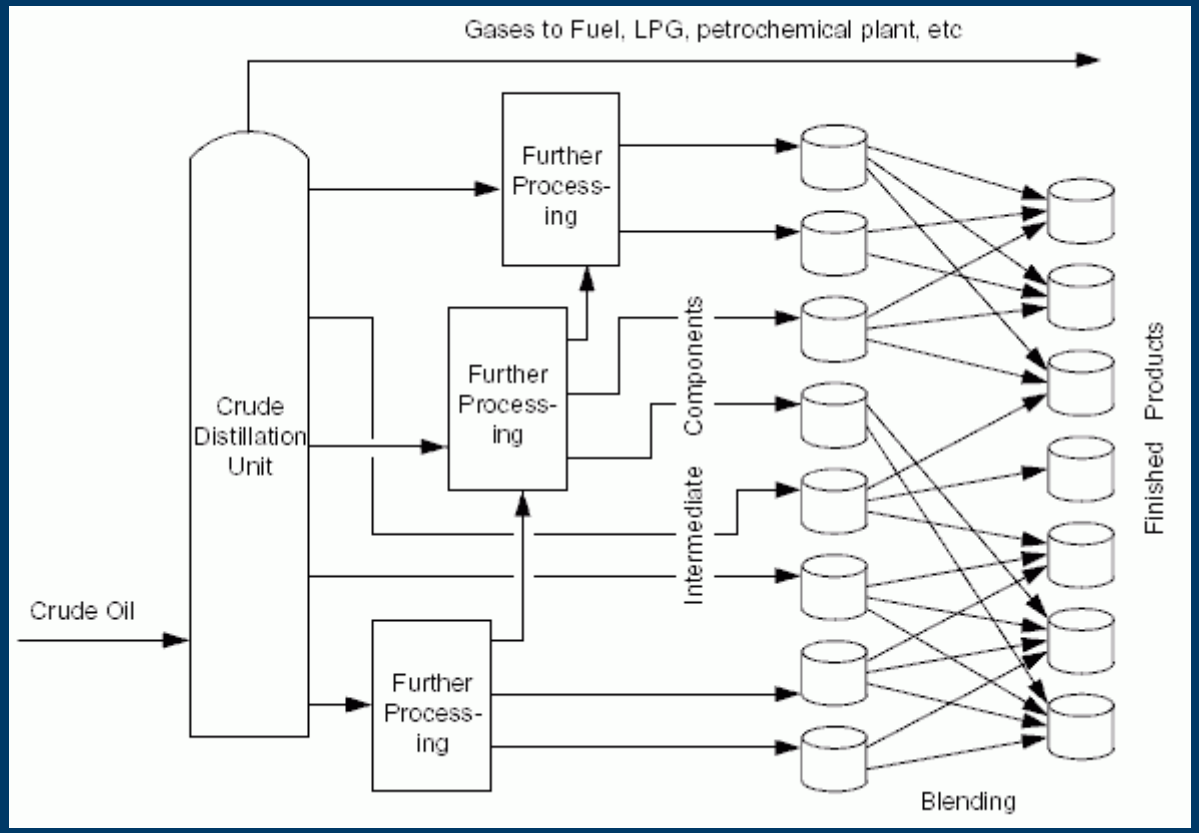
Better than the optimum?

- Optimisation in a refinery

From a modelling point of view, a refinery consist of a series of:
process units
which transform:
materials
into one another.
Materials may also be:
Blended to make
finished products
which are subject to
Quality and other
specifications.


Gases to Fuel, LPG, petrochemical plant, etc
Further Process-ing
Further Process-ing
Further Process-ing
Crude Distillation Unit
Crude Oil
Components
Intermediate
Finished Products
Blending

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Constraint on Sulphur

Indian Diesel Specification required meeting Bharat Stage II, III, & IV Emission Norms[2]				
Characteristics	Unit	Bharat Stage II	Bharat Stage III	Bharat Stage IV
Implementation date		2001 (selected cities), 2005 (nationwide)	2005 (selected cities), 2010 (nationwide)	2010 (selected cities)
Ash, max	% mass	0.01	0.01	0.01
Carbon Residue (Ramsbottom) on 10% residue, max†	% mass	0.3	0.3	0.3
Cetane Number (CN), min	-	48*	51	51
Cetane Index (CI), min	-	46*	46	46
Distillation 95% vol. Recovery at °C, max	°C	-	360	360
Flash point Abel, min	°C	35	35	35
Kinematic Viscosity @ 40 °C	cst	2.0-5.0	2.0-5.0	2.0-4.5
Density @ 15 °C	Kg/m^3	820-860 (820-870)*	820-845	820-845
Total Sulfur, max	mg/kg	500	350	50

Recent Specs.

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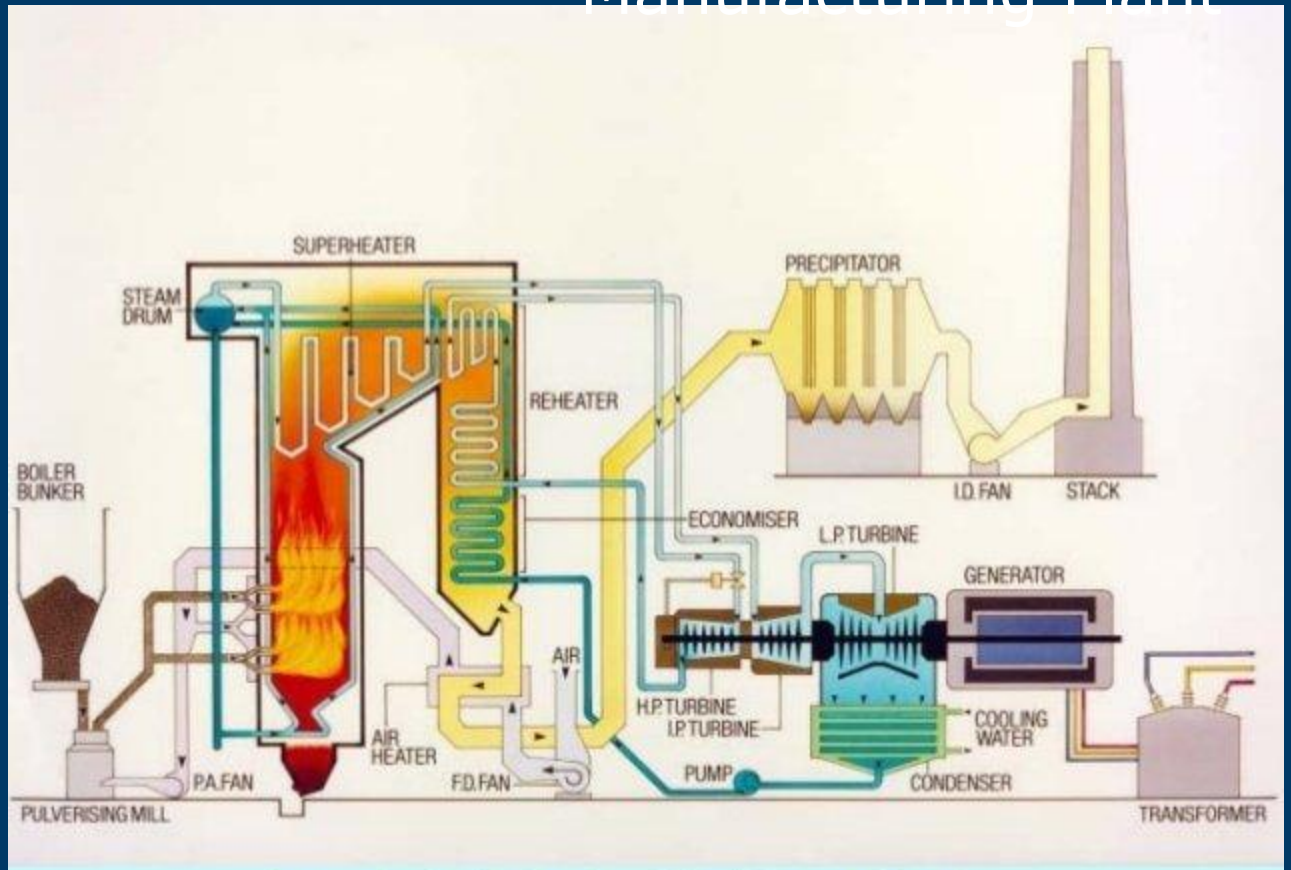
Optimisation in Power generation Equipment Manufacturing Plant



Layout of a Pulverized Fuel Power Plant

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Axial Profile Fan balancing

- Axial Profile Blades made in Germany
- 23 blades in a fan assembly
- Assembled with Hub and shafts made locally
- Unbalanced Fan assemblies
- Delay in Shipment

Requirement rest eccentricity < 5 microns.

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Optimal assignment of Blades to Positions

But the result from the shop floor was unpalatable!

What went wrong?

Blade Number	Position
1	20
2	18
3	2
4	8
5	4
6	7
7	10
8	22
9	12
10	15
11	6
12	9
13	16
14	21
15	1
16	19
17	3
18	13
19	14
20	17
21	11
22	23
23	5

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Going to the moon is easy but crossing the road is so difficult.

- (attributed to) Lawrence Peter

Nothing is new except arrangement

- W. Durant

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ESP manufacturers the world over strengthen the R&D efforts and come out with innovations on mechanical, electrical and control system components of the ESPs, to achieve following objectives:

- To make ESPs operationally reliable
- Higher precipitation efficiency
- Optimisation of ESP size
- Suitability for high resistivity dust applications
- Reduction in operation/maintenance costs

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ESP Bids lost

- International competition for supply of ESP to specs on inlet dust burden and required efficiency
- Many bids were lost to Japanese competition
- The CEO was interested in finding why
- Culprit was the weight of the ESP
- Can the weight be reduced and by how much?

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ESP Schematic Diagram

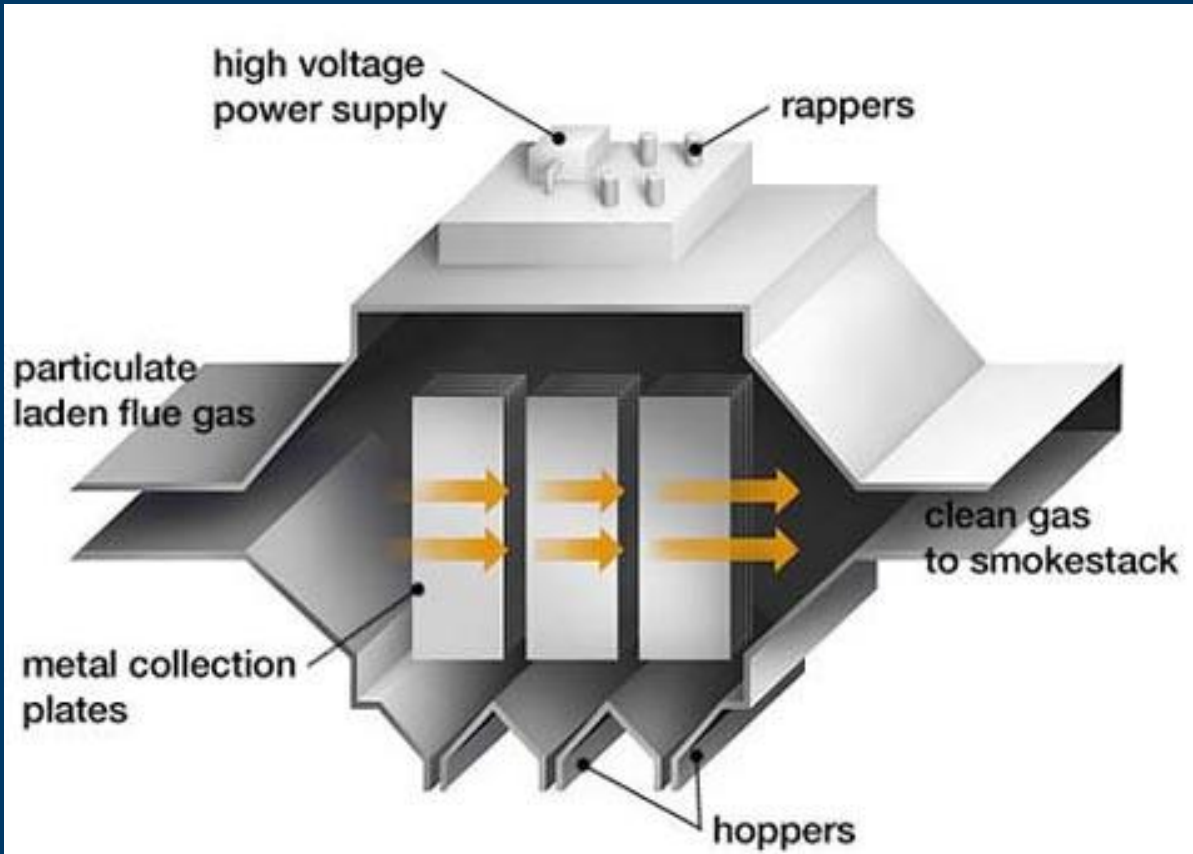

Diagram courtesy of http://www.zet.com/techrefs_overview_fr.html

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Current Practice

- Use of a dedicated software to design the ESP
- Design many ESPs varying parameters to achieve required efficiency under given restrictions
- Select the best among the Designs

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If you are hunting rabbits in tiger country, you must still keep your eye pealed for tiger, but when you are hunting tigers you can ignore the rabbits.

- H. Stern

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Mathematical Programming Approach

- Formulate the prediction of Efficiency and weight based on basic parameters like number of fields, height, width and Length as a non linear regression problems
- Formulate the ESP design problem as a Math programming problem
- Select an Optimal design minimising weight subject to efficiency requirement.

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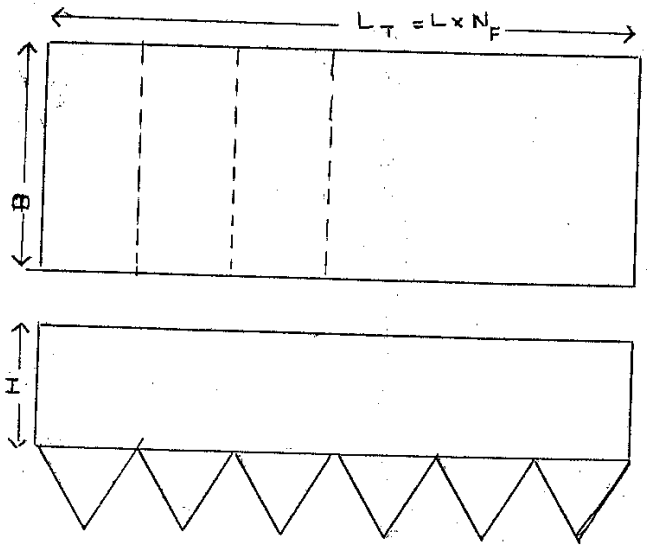
Schematic Diagram of EP:

Legend :

L_T	=	total length
L	=	effective length of a field
B	=	Width of EP
H	=	height of EP
N_F	=	number of fields.



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Results and surprises

- The design options found were less in weight by 20 to 30 tonnes
- However the design Engineers refuted
- DGM came into settle the dispute
- Finally Math programming approach was upheld

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Questions?

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False Fire Alarms

- Is there a method in madness?
- 60,000 activations
- Some descriptive data plus remarks by firemen
- Simple analysis – stratification
- 70% of the variation can be explained
- Affinity Testing – Analysis of language data

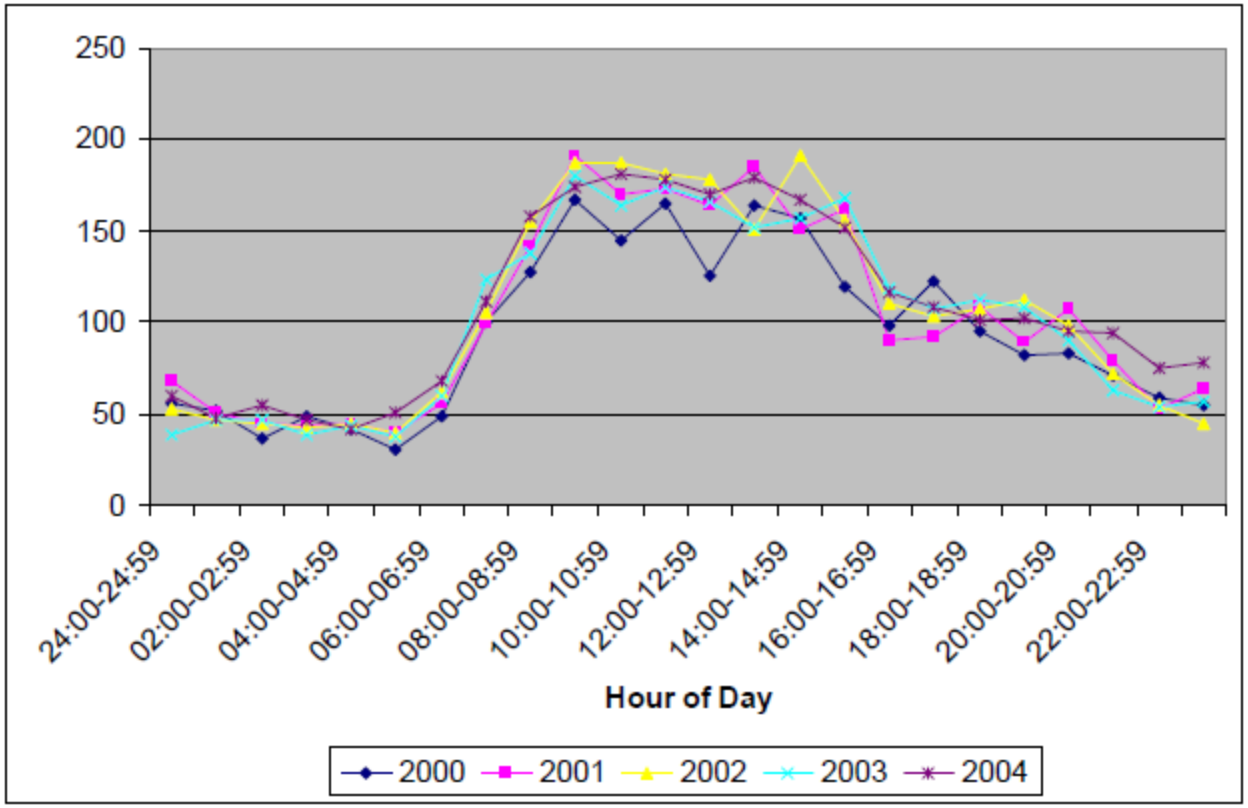

Figure 7: False & Unwanted Fire Alarms on the Day of Week in Auckland CBD in Total (2000-2004)

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Reason grouping	Incidence	Percentage
Maintenance - Alarm System	42	21%
Environmental Factors - Internal Occupant Negligence/Inappropriate System	32	16%
Contractors – Non-fire system	20	10%
Contractors - Fire system	20	10%
Human Cause – Accidental	19	9%
Unknown/Not Investigated	19	9%
Environmental Factors - External	10	5%
Maintenance – Building	8	4%
Human Cause – Malicious	8	4%
Poor fit for purpose	7	3%
Random External Factors	6	3%
Good Intent	7	3%
Intentional Tampering with System	6	3%
Total	204[25]	100%

Table 15: Affinity Grouping of False Activations

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Thanks for your patience.

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Quadratic assignment formulation for the Fan blade sorting problem

Minimise $V + W$

Subject to:

$$\sum_{i=1}^{23} \sum_{j=1}^{23} \left(M_j \text{ Sin } \left(\frac{360}{23}(i)\right) X_{ij} - V + W = 0 \quad \ldots(1)$$

$$\sum_{i=1}^{23} \sum_{j=1}^{23} \left(M_j \text{ Cos } \left(\frac{360}{23}(i)\right) X_{ij} \leq \epsilon \quad \ldots(2)$$

$$\sum_{i=1}^{23} \sum_{j=1}^{23} \left(M_j \text{ Cos } \left(\frac{360}{23}(i)\right) X_{ij} \geq \epsilon \quad \ldots(3)$$

$$\sum_{i=1}^{23} X_{ij} = 1 \text{ for all } j \text{ from } 1 \text{ to } 23$$

$$\sum_{j=1}^{23} X_{ij} = 1 \text{ for all } i \text{ from } 1 \text{ to } 23$$

$$X_{ij} = 0 \text{ or } 1 \text{ for all } i, j; U, V \geq 0$$

where ϵ = Specified unbalancement limit.