Generating FIFO Schedules from Crew Rosters

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Agenda

- *Problem Definition*
- *High Level Approach*
- *Path vs Arc*
- *Formulation*
- *Implementation*
- *Results*

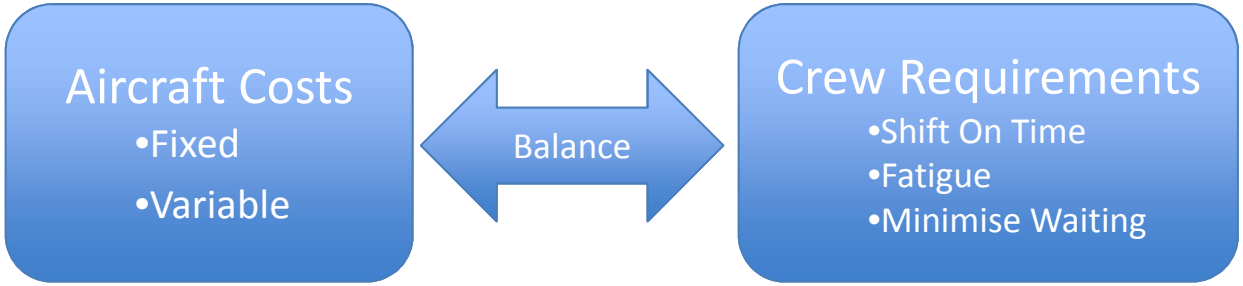
Problem

Strategic Problem

- How many Aircraft, and of what type, are required to service FIFO needs over the next 15 years given predicted roster demands?
- What does the flight schedule look like?
- How does the schedule cope with unplanned disruptions?

Problem (cont)

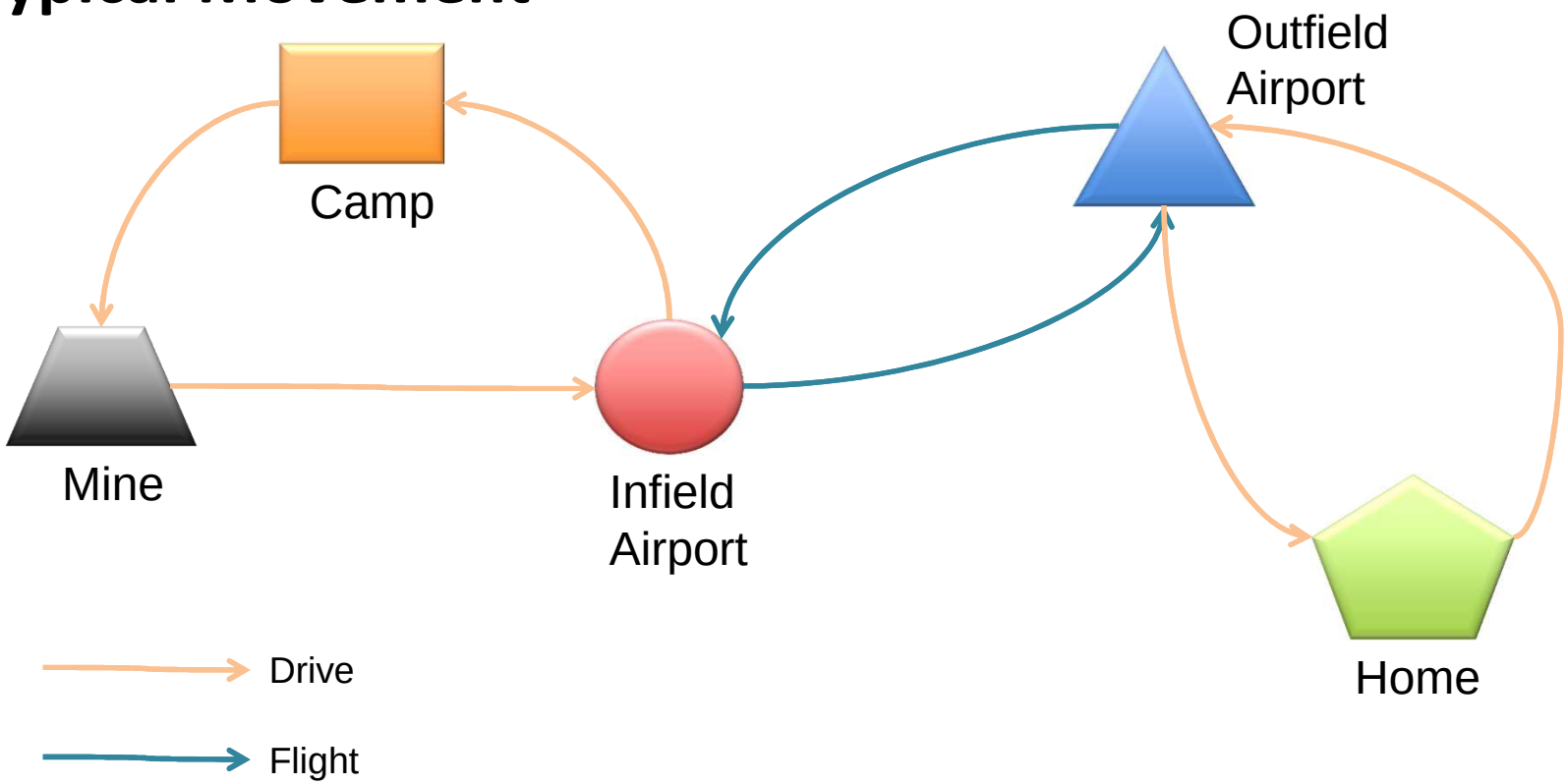
Overview



- Aircraft need to return to starting positions at the end of the day
- Multiple source and destination locations
- Aircraft not restricted to shuttle runs (i.e. Can fly to/from any location)
- Min turnaround times at airport
- No Milk Runs
- Minimise time at infield airports

Problem (cont)

Typical Movement



Problem (cont)

Example Roster Patterns

Roster Pattern	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56
10on/4off	D	D	D	D	D	D	D	D	D	D																																															
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4on/2-4off	D	D	D	D					D	D	D	D																																														

Problem (cont)

Crewing Optimiser Costs

- ***On time Arrival:*** *Cost for every minute after the start of their shift*
- ***Waiting Time:*** *Cost for every minute early*
- ***Fatigue:*** *Cost for every minute over the fatigue limit**
- ***Priority:*** *Factor applied to cost*

**Fatigue Limit defined as the maximum time allowed from leaving home to the end of their first shift*

Need to know the start and end time of both the first and last shift in the work block to determine these costs.

Problem (cont)

Inputs

Locations
- Airports
- Mines
- Camps

Shift Details
- Start/End day and time
- Rotation patterns (e.g. 21/7)
- Priority
- Rest Requirements

Workgroup Details
- Types
- Origin Location Split (e.g. 50% BNE, 30%Townsville, 20%Goldcoast)
- Numbers (scaled over 15 years)
- FIFO Take-up Rate
- Airport and Camp mapping

Aircraft
- Type
- Capacity
- Number
- Starting Positions

Airport
- Bays
- TT, TL, LL, LT times
- Turn around time (by loc & aircraft type)

Land Travel Matrix (i.e. Airport to camp, camp to mine, mine to airport durations)

Air Travel Matrix (Location pairs, duration, aircraft type, cost)

Problem (cont)

Outputs

Shift Demands (intermediate result of demand generator)

Aircraft Type Details

- Max number used for each aircraft type

Flight Details

- From/To location
- From/To time
- Aircraft type
- Used Capacity
- Cost
- Bay Usage (i.e. Bay waiting time)
- Break down of people travelling on flight by workgroup

Workgroup Details ("mirror" of Flight Details)

- Workgroup
- Amount
- Shortfall
- Fatigue, Waiting, Late cost and duration
- Break down of flights

Airport Details: for each time step

- Aircraft Type
- Number
- Landings For Hour
- Takeoffs For Hour
- Arriving Passengers
- Departing Passengers
- Total Passengers in terminal

High Level Approach

1. Generate All Shift Demands from Roster demand for time range (e.g. 15 years)
   - Travel Date
   - From Location (e.g. Brisbane)
   - To Location (e.g. Mine)
   - Shift Start Time
   - Shift End Time
   - Number of people
   - Priority
   - Workgroup
2. Select one day to generate FIFO schedule
   - e.g. Often the "busiest" day for a year of interest
3. Generate desired demands/sources at airports (numbers and times) to be serviced by flights
   - Takes into account bus travel times between airport, camp and mine
   - Required rest durations
   - Duration from leaving home to flight departure
4. Optimise
5. Results

Path vs Arc Formulation (cont)

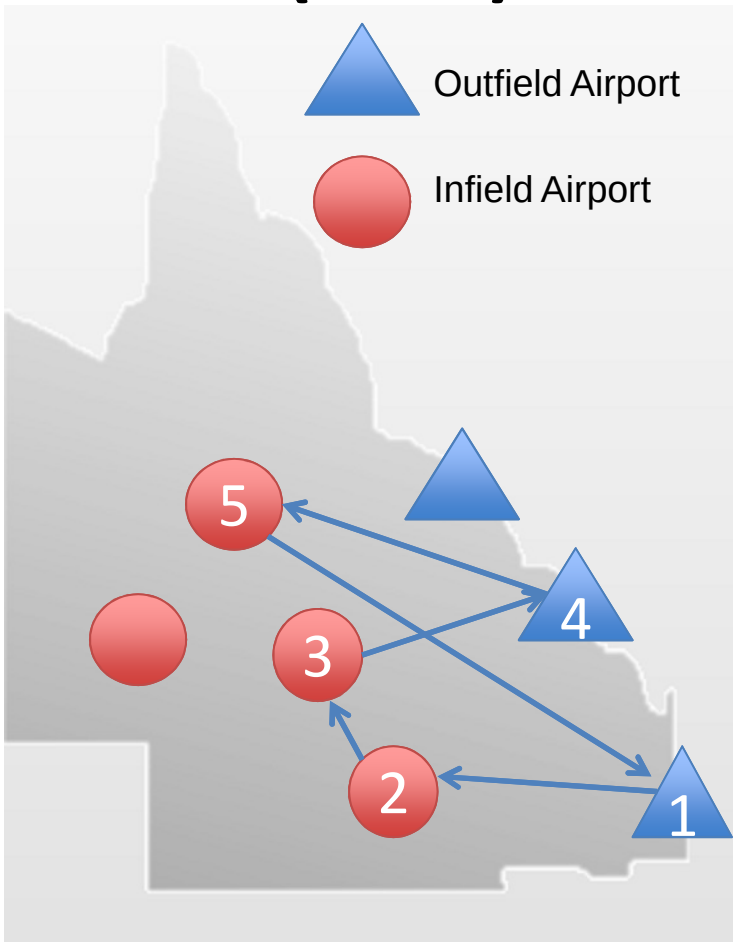
Path Based Formulation

Generate the full path for a plane for a day

Advantages

- Easier to control what a plane does in a day
  - Sequence of arcs
  - min/max flying time in a day
  - Pilot flying/fatigue issues (i.e. Change over locations)
  - Refuelling points
- Easy to ensure minimum and maximum turn around times satisfied
  - Plane must be at a gate for at least 30 minutes
  - Can't stay at the gate longer than 3 hours*

*Bay usage at infield airports is an important resource so should be kept to a minimum. The upper limit was more of a preference than a well defined rule



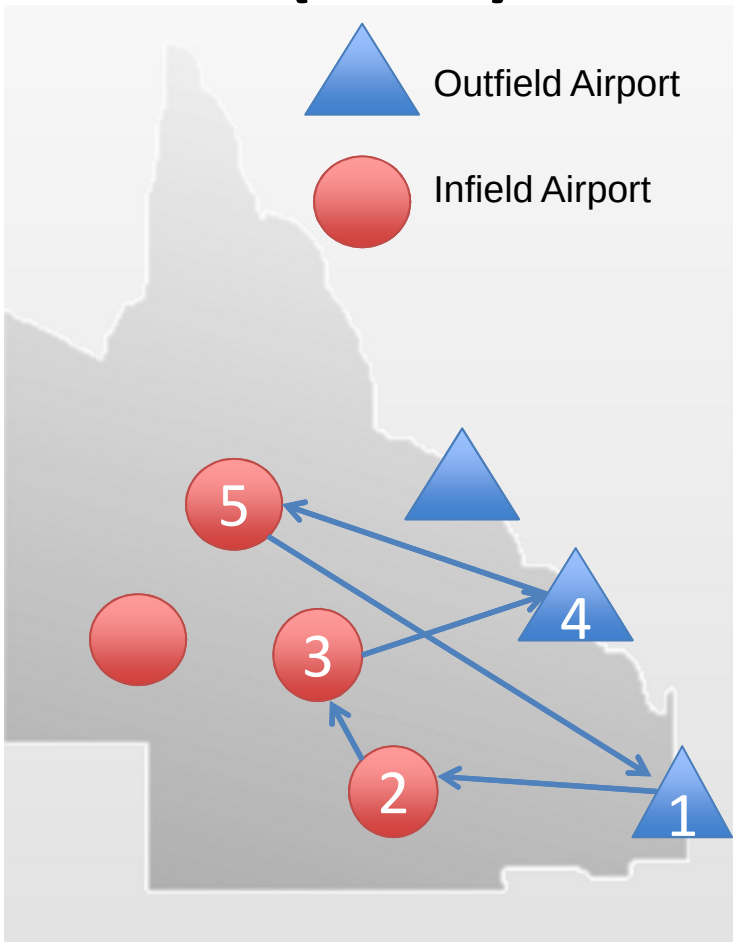
Path vs Arc Formulation (cont)

Path Based Formulation (cont)

Disadvantages

- Client was not asking for additional control that path based approach offered.
- Complex routes are acceptable and thus there are too many path options to consider using them all at once. These combinations not only include the sequence of arcs, but also their timing

  (probably could have been solved by using an intelligent subset)



Arc Sequence	Route Timing
•1-2-1	•1-2(30min)-1
•1-2-3-1	•1-2(31min)-1
•1-2-3-4-1	•1-2(32min)-1
•etc	•etc

Path vs Arc Formulation (cont)

Arc Based Formulation

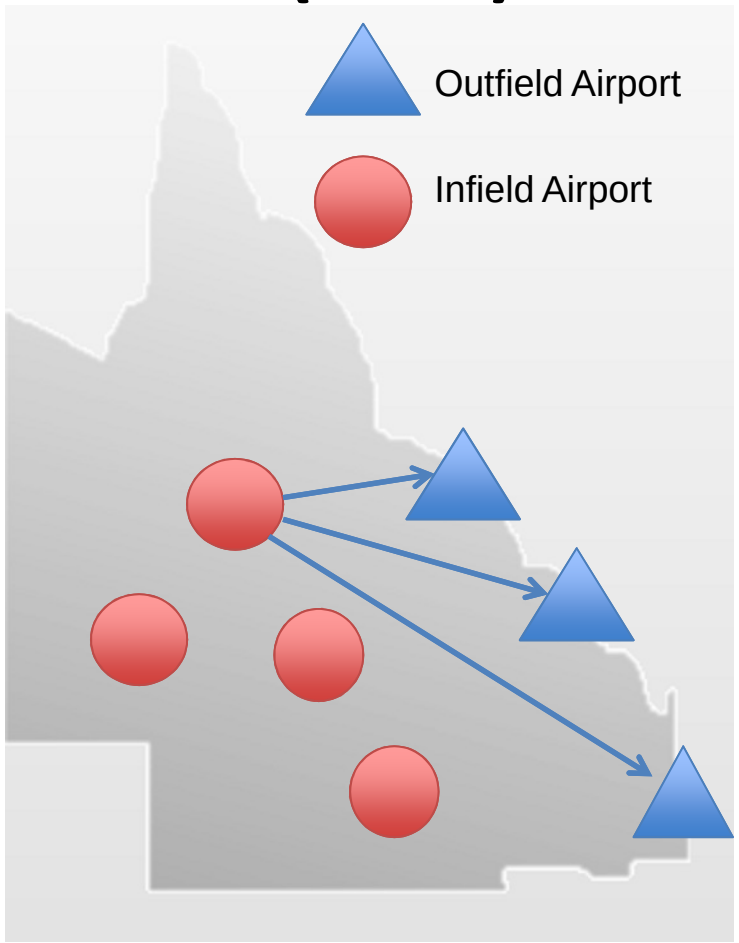
Only generate the arcs for formulation and create paths using post processing.

Advantages

- More scalable. Only need to generate the arcs between pairs of locations. More likely to be able to generate all possible combinations over time and still solve.

Disadvantages

- Have less control over the routes generated (both sequence and timing)
- Need to generate paths from the solution (which is fairly straight forward)
- Need to include turnaround constraints in formulation.



Implementation

Arc Based Approach

- Relatively simple strategic problem
- Could be extended to path based if required
- Other advantages already mentioned

Optimiser pre-processing

- Generate ALL possible flights(arcs) for every time step (2.5 minutes for 24hrs)
- Calculate crew cost matrix (cost of putting someone from every workgroup on every flight). Can do this because once you know the flight you can determine lateness, fatigue and waiting time.

Solve

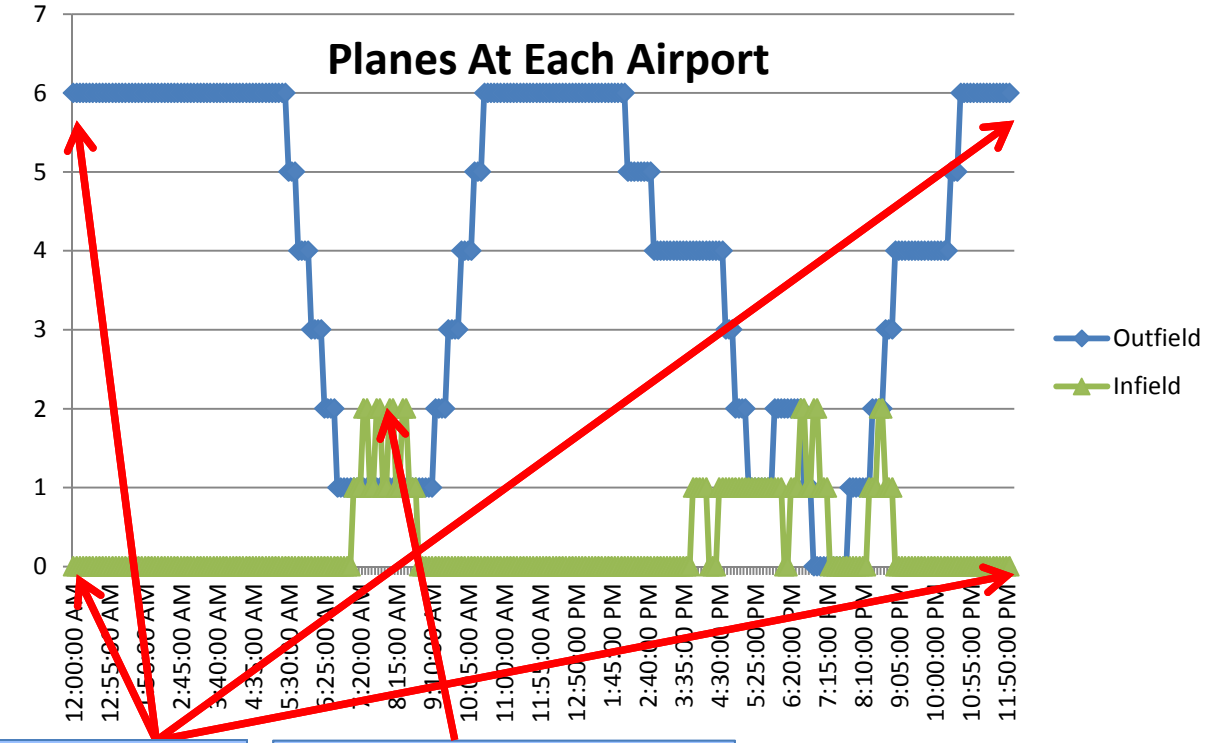
- Problem was simple enough that no special heuristics were required

Optimiser post-processing

- String together flights to generate paths for individual planes

Results

KPI	Value
Total Planes	6
Number of Flights	24
Flight Cost ($)	72000
Fixed Cost ($)	4800
Total Cost ($)	76800
Flight Duration (minutes)	2352
Total People Movements	1248.073
Shortfall	**16.513**
Total Fatigue (minutes)	425061
Total Late (minutes)	0
Total Waiting (minutes)	59205
Fatigue Cost	0
Late Cost	0
Waiting Cost	592.05
Plane Utilisation (%)	70.27



Planes Balanced

Large Volume From Infield

Results

Index	From Location	To Location	From Time	To Time	ID	Used Capacity	Bay Usage
1	Outfield	Infield	5:30	7:10	T_1	9.3	25
2	Outfield	Infield	5:45	7:25	T_2	66.6	30
3	Outfield	Infield	6:05	7:45	T_3	66.6	30
4	Outfield	Infield	6:25	8:05	T_4	0	30
5	Outfield	Infield	6:45	8:25	T_5	0	25
6	Infield	Outfield	7:35	9:15	T_1	66.6	295
7	Infield	Outfield	7:55	9:35	T_2	66.6	315
8	Infield	Outfield	8:15	9:55	T_3	66.6	405
9	Infield	Outfield	8:35	10:15	T_4	66.6	400
10	Infield	Outfield	8:50	10:30	T_5	51.102	405
11	Outfield	Infield	14:10	15:50	T_1	62.685	25
12	Outfield	Infield	14:50	16:30	T_2	62.685	100
13	Infield	Outfield	16:15	17:55	T_1	28.751	45
14	Outfield	Infield	16:40	18:20	T_3	55.107	25
15	Outfield	Infield	16:55	18:35	T_4	66.6	30
16	Outfield	Infield	17:15	18:55	T_5	66.6	25
17	Infield	Outfield	18:10	19:50	T_2	66.6	N/A
18	Outfield	Infield	18:40	20:20	T_1	66.6	25
19	Infield	Outfield	18:45	20:25	T_3	66.6	N/A
20	Outfield	Infield	18:55	20:35	T_6	66.6	25
21	Infield	Outfield	19:05	20:45	T_4	66.6	N/A
22	Infield	Outfield	19:20	21:00	T_5	66.6	N/A
23	Infield	Outfield	20:45	22:25	T_1	46.043	N/A
24	Infield	Outfield	21:00	22:40	T_6	0	N/A

Repositioning Movements

Variable Bay Usage

Aircraft Return to Starting Position

Aircraft Usage Variable

Unplanned Disruptions

Approach

- Solve entire problem assuming no disruptions
- Freeze solution up to disruption point
- Optimise under new conditions
- (do this for each unplanned disruption)

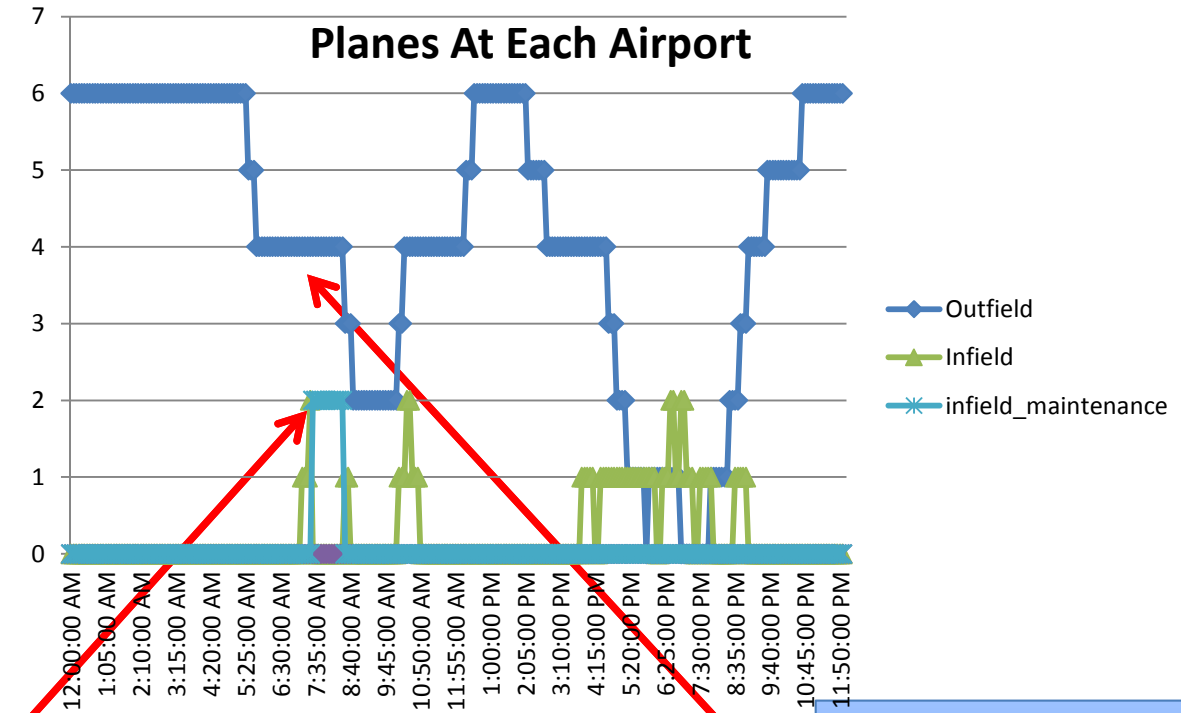
Problems

- Aircraft in bays when become unavailable
  - Creation of ‘maintenance bays’
- Flights in progress when disruption occur
  - ‘not quite frozen’
  - If they can make the destination the optimiser used them, otherwise they stay grounded.
    (in reality the might turn the flight back or find an alternative landing site)

Results (unplanned disruptions)

Scenario: No bays available at infield airport from 7:30 to 8:30

KPI	Value
Total Planes	6
Number of Flights	26
Flight Cost ($)	66000
Fixed Cost ($)	4800
Total Cost ($)	70800
Flight Duration (minutes)	2156
Total People Movements	1135.982
Shortfall	128.604
Total Fatigue (minutes)	413793
Total Late (minutes)	9590
Total Waiting (minutes)	66656
Fatigue Cost	0
Late Cost	959000
Waiting Cost	666.56
Plane Utilisation (%)	69.78



Planes In Maintenance

No Departures during disruption

Questions ?

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