Modelling and Understanding Airport Operations

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Theory LANCS Practice

Key aims: Understanding and Modelling the Real Airport Operations

Understand the real systems, bridging the gap between the simplified academic models of the past and the real problems at the airports. Develop the underlying theory for the real problems, adapting existing theory as appropriate.
Utilising projects to develop integrated simulation and optimisation algorithms to take into account the real constraints upon arrival and departure runway sequencing, ground movement, stand allocation and the associated resource allocation for stand operations.

Airport and TMA operations overview

Terminal Manoeuvring Area (TMA) operations
Aircraft enter the local airspace around the airport (the TMA)
Aircraft may delay by circling in stacks before flying to the airport
Either use standard arrival routes or solve the individual routing problems

Arrival runway sequencing: Landing sequence affects runway throughput

Taxi-in operations: Taxi from landing runway to stands

Unloading operations: Passengers and baggage unloaded at the stands

Potential tugs between stands: May need tug from arrival to departure stand

Loading operations: New passengers, baggage and fuel are loaded

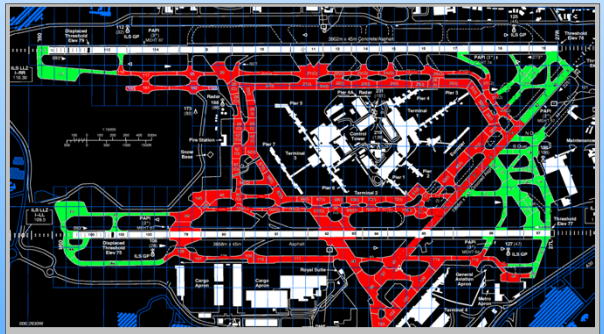
Push-back operation: A tug is used to push loaded aircraft back from stand

Engine start-up: Usually occurs in the cul-de-sacs or taxiways near the stands
Requires space behind aircraft. May block taxiway/cul-de-sac/other stands

Taxi-out operations: Taxi from stands to queues by departure runway end

Departure runway sequencing: Take-off sequence affects departure rate
Aircraft often re-sequenced in holding areas near runway ends
May be multiple queues, may allow interchange between queues

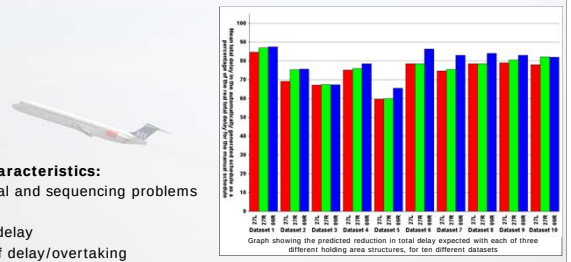
Terminal Manoeuvring Area operations (TMA)
Aircraft usually use standard departure routes through TMA



Layout of London Heathrow airport (2004)
Two runways (in white)
Four terminals (white) with multiple piers. Cul-de-sacs between piers
Taxiways to move around airport (red)
Holding areas for take-off sequencing (green)

Departure Runway Scheduling (2003-2006)

Aim: Provide good take-off sequencing advice to runway controller



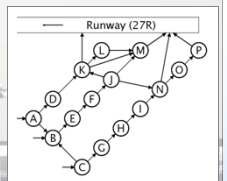
Graph showing the predicted reduction in total delay expected with each of three different holding area structures, for ten different datasets

Key Problem Characteristics:
- Combined spatial and sequencing problems

Objectives:
- Reduce overall delay
- Limit inequity of delay/overtaking
- Take-off within time-slots

Constraints:
- Sequence-dependent separations
- Take-off time-slots
- Limited re-sequencing opportunities from taxiway structures

Solution method adopted:
- Meta-heuristic 'Tabu Search' to investigate sequences
- Fast heuristic path allocation using controller preferences
- Fast heuristic check to verify that re-sequencing is possible



Directed graph model of one of the holding areas (27R) which is used for re-sequencing aircraft before take-off

Target Start-At Time Allocation (2008-)

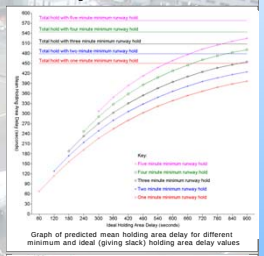
Aim: Determine a pushback and engine start-up time for aircraft so that more of the necessary delay at busy times is absorbed at stand rather than runway

Key Problem Characteristics:
- Two combined sequencing problems:
  - –Most stands are around cul-de-sacs: aircraft block other aircraft
  - –Blocking times are aircraft/sequence dependent
  - –Sequence-dependent take-off separations

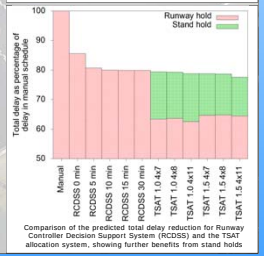
Objectives:
- Predict good take-off sequences
  - –Reduce delay, limit inequity, time-slot compliance
- Allocate appropriate amount of delay as stand hold
  - – Min & ideal runway hold times (slack) are parameters

Constraints:
- Take-off separations and take-off time-slots
- Blocking times for pushbacks – block other stands during pushback or startup

Solution method adopted:
- Branch and bound within a rolling window



Graph of predicted mean holding area delay for different minimum and ideal (giving slack) holding area delay values



Comparison of the predicted total delay reduction for Runway Controller Decision Support System (RCDSS) and the TSAT allocation system, showing further benefits from stand holds

Arrival Scheduling (2009-)

Aim: Obtain good, easily achievable landing sequences

Objectives:
- Reduce overall delay, inequity and missed time-slots

Constraints:
- Sequence dependent landing separations
- Landing time windows
- Limitations of stacks
  - – Costly to take from other than bottom
- Incoming flight paths
  - –Interaction between arriving flights
  - –And other flights?
  - –Use Standard flight paths or not?

Ground Movement (2009-)

Aim: Reduce environment effect of airports by considering ground movement

Objectives:
- Route aircraft around an airport
- Sequence aircraft at points of contention
- Improve taxi time predictions
- Reduce fuel burn

Constraints:
- Taxiway structure limits movement
- Minimum inter-aircraft separations are required
- Time-windows for source and destination

Stand Operations (2009-)

Aim: Model the operations which occur at the stands in order to improve completion time predictions and improve operational efficiency

Problem structures:
- Similar to stand allocation and production or project scheduling problems
- With additional problem-specific constraints

Examples:
- Baggage sorting station allocation
  - –Reuse sorting stations for destinations
- Pushback tug allocation
  - –Limit tug travel distances between stands
- Stand alteration to improve resource usage
  - –e.g. taxi times, fuel usage, time other aircraft are blocked for,...

Stand Allocation (Planned 2010-)

Aim: Allocate stands to improve environmental effects

Objectives:
- Reduce environmental effects by intelligently allocating stands
- Consider effects upon ground movement and runway sequencing
  - –Stand allocation to avoid congestion at stands
  - –Stand allocation to reduce fuel burn taxiing

Constraints:
- Stand allocation restrictions for airlines or aircraft size/type
- Shadowing constraints upon nearby stand occupancy
- Inter-stand pushback or arrival time constraints – scarce taxiway resources

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