Destination Green

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Potential Benefits of Operations

John-Paul B. Clarke

Associate Professor
Daniel Guggenheim School of Aerospace Engineering and
H. Milton Stewart School of Industrial and Systems Engineering
Director, Air Transportation Laboratory
Georgia Institute of Technology

Introduction

- Inefficiencies in air traffic operations generally result in unnecessary noise and emissions
- Current global drive (e.g. NextGen in US, SESAR in Europe) to increase the capacity for and the efficiency of air traffic operations could have significant environmental benefits, especially with respect to emissions
- Important to understand and quantify the environmental benefits of these planned changes

Potential Improvements (1)

- CDA/OPD
  - Design and introduce continuous descent arrival / optimized profile descent procedures that reduce noise, fuel burn, emissions, and flight time
- Stochastic RTA
  - Consider the effects of uncertainty and any potential recourse when determining required times of arrival to ensure that they can be met with high confidence while at the same time minimizing expected fuel consumption

Potential Improvements (2)

- Optimal Gate Assignments
  - Assign flights to gates to reduce passenger walk times as well as aircraft delay due to ramp and taxiway congestion
- Optimal Pushback Times
  - Set gate pushback times for departing flights to minimize taxi-out time while ensuring runways are fully utilized

Potential Improvements (3)

- Optimal Airport Configuration
  - Determine airport configuration with the greatest expected throughput (considering potential configuration changes) given project demand and weather
- Stochastic Runway Scheduling
  - Determine the best “planned” schedule of operations on a given runway considering the effects of uncertainties and actions that can be taken in response to them

Potential Improvements (4)

- Optimal assignment (to runways) and scheduling (at fixes and runways) of arrivals
  - The “Opera/Theatre Problem”

Optimal Arrival Assignment and Scheduling Problem

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- Determine
  - Assignment of arrivals to runways
  - Schedule of “crossing times” at entry fixes and “landing times” at runways
- Given
  - Capacity of runways and fixes
  - Flight distances and speeds for each runway-fix pair
  - Taxi distances and speeds for each runway-gate pair
  - Aircraft performance

Model Overview

- Objective
  - Minimize total emissions in terminal area and on the airport surface
- Assignment problem
  - Assign arrivals crossing given “entry fix” to one of the two runways to which they may be assigned
- Sequencing problem
  - Sequence arrivals assigned to each runway

Physical Constraints

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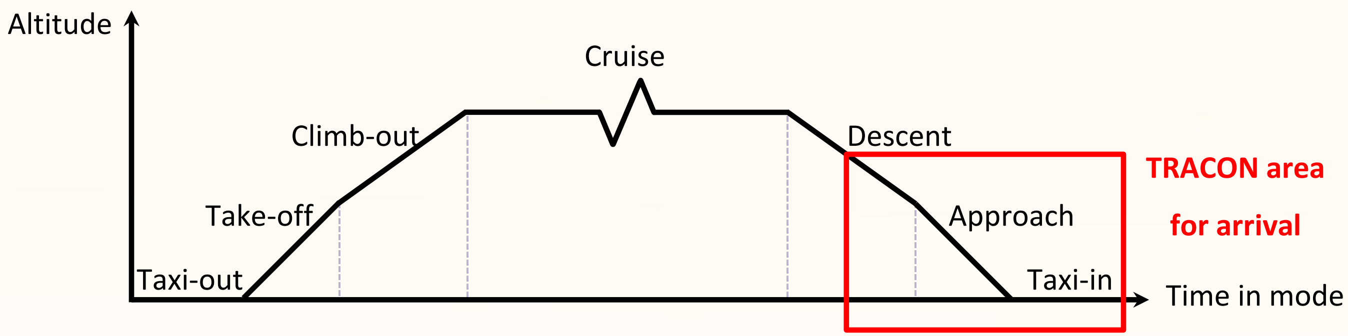
- Terminal Area Paths
  - Aircraft follow specified transit paths within terminal area
  - Terminal area paths must vertically separated
  - Aircraft cannot overtake other aircraft on the same path
  - Transit time is known
- Spacing
  - Minimum separation requirements must be satisfied at each fix and runway

Total Emissions Cost



- Objective Function

$$\min \underbrace{\sum_{i\in A} C_i^T}_{\text{transition}} + \underbrace{\sum_{i\in A} E_i^H F_i^H \left(t_i^F - S_i^F\right)}_{\text{delay}} + \underbrace{\sum_{i\in A}\sum_{k\in R_{Arr}} E_i^S F^S T_i^S(k)\, r_{ik}}_{\text{surface}}$$

$E_{jk} = t_j \times FF_j \times EI_{jk}$

E_{jk} :emission of pollutant k in mode j, (g)

t_j :time in mode j ,(sec)

FF_j :mode-specific fuel flow rate in mode j,(kg/sec)

EI_{jk} :emission index for pollutant k in mode j, (g/kg)

Engine:AE3007A1/1	Take-Off	Climb-Out	Approach	Idle/Taxi
EI HC(g/kg)	0.03	0.03	0.03	3.88
EI CO(g/kg)	0.74	0.55	6.8	40.07
EI NO_x(g/kg)	16.10	14.01	7.12	4.17
Fuel Flow(kg/sec)	0.3805	0.3163	0.1125	0.0459

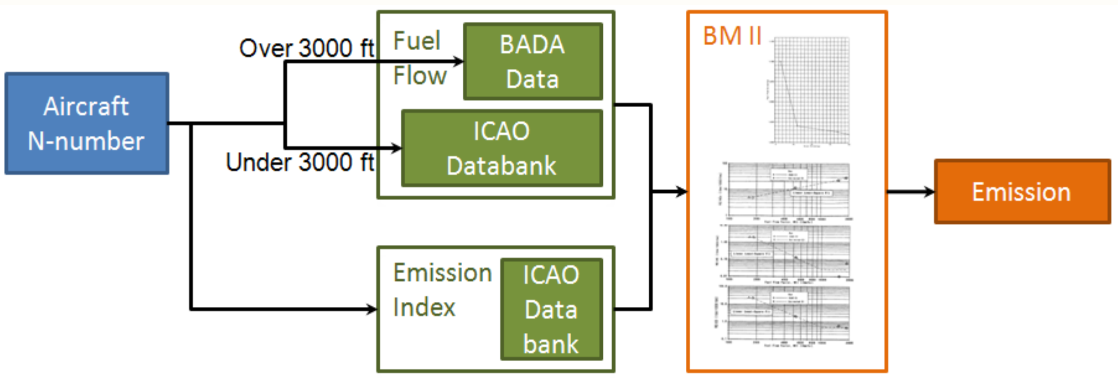
<Sample of ICAO databank>

Terminal Area Transition Cost

- Emissions cost for transition

$$C_i^T = \sum_{k \in R_{Arr}} \sum_{l \in F_{Arr}} f_{il} r_{ik} \sum_{t_{lk}=0}^{T_i^T(l,k)} E_i^T(t_{lk}) F_i^T(t_{lk}) time_{step}, \ \forall i \in A$$

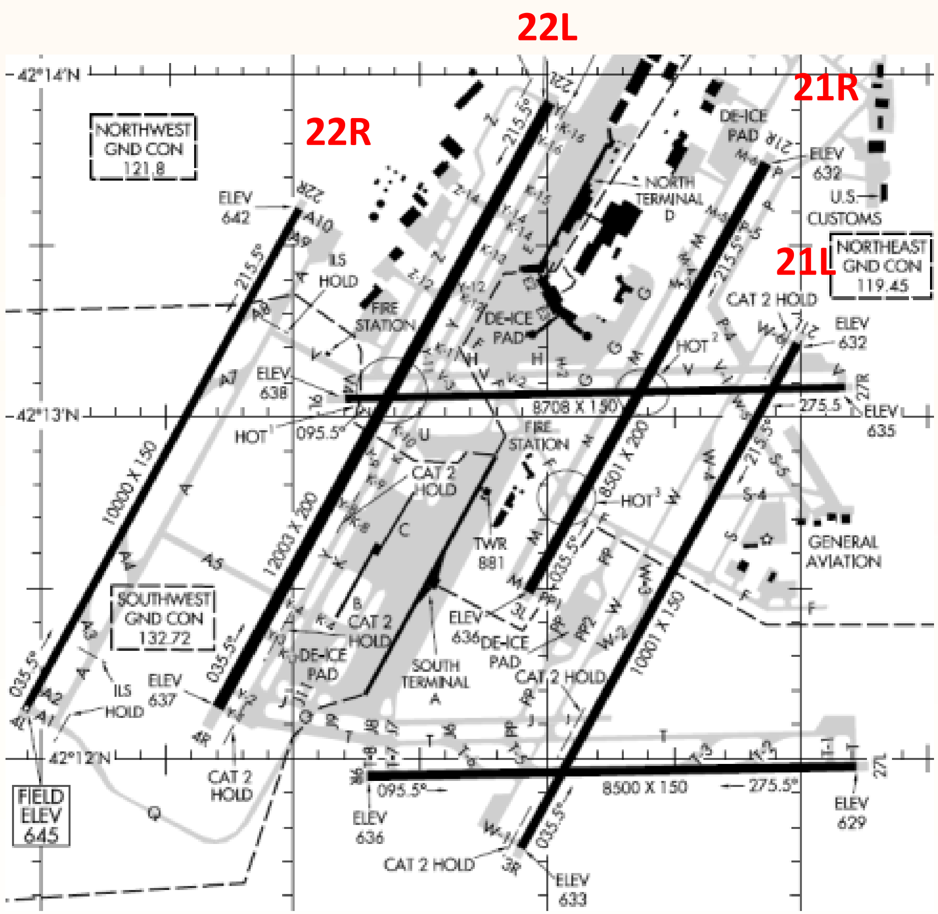
  - Emission indices obtained from ICAO databank
  - Boeing Method II used to correct for installation effect on fuel flow, and temperature and altitude effect on emission indices



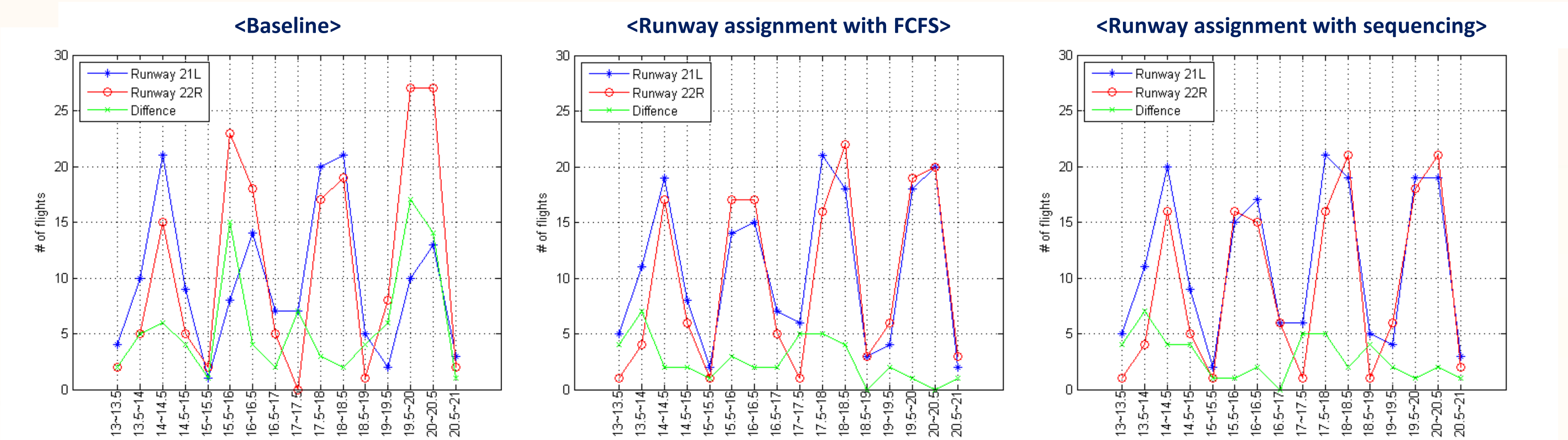
Computational Study

- Detroit Airport
  - 10 January 2007
  - Runway configuration 21L,22R || 21R,22L
  - 331 arrivals and 310 departures between 13:00 and 21:00
- Three cases:
  - 1: Assigned to closest runway + FCFS (baseline)
  - 2: Assigned to optimal runway + FCFS
  - 3: Assigned to optimal runway + optimal sequence

Detroit Airport

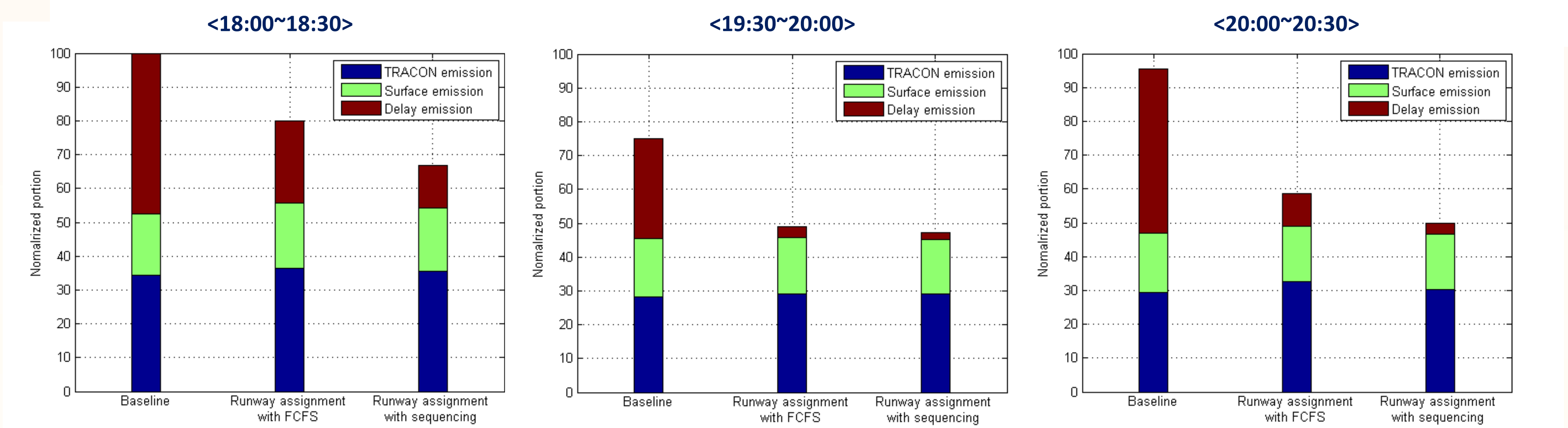


Computational Results (1)



- Poor utilization of runways (in baseline) due to flow imbalance

Computational Results (2)



- Significant reduction in delay emissions (at arrival fix)
- Assignment more beneficial than sequencing in reducing surface and delay emissions

Compared to baseline	TRACON emission	Surface emission	Delay emission	Total emission
Runway assignment with FCFS	103.8%	97.8%	30.5%	75.8%
Runway assignment with sequencing	102.6%	96.4%	17.1%	70.1%

Conclusion

- Assignment and scheduling of arrivals can reduce emissions costs by up to 29.9%
- Optimal assignment of arrivals to runways is more important that optimal sequencing of landings on runways in terms of reducing emissions