NASA’s Research on an Integrated Concept for Airport Surface Operations Management

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Fuel Consumption at DFW

- Analyzed surface data for three months in 2008
- Estimate 120,000 kg of fuel used in surface operations per day
- Approximately 21,600 kg or 6,980 gallons of fuel in stop and go per day
- Converted to a year, approx 5 million USD

DFW Airport

- Currently, aircraft delays at runway queue
- Excess taxi-out times, fuel consumption and emissions
- Departure metering: limiting aircraft near runway and taxiways
Potential Benefits of Airport Departure Metering

• Two recent FAA sponsored studies:
  – At 8 major US airports, cumulative fuel savings of **$2.3 billion USD** from 2010 to 2030\(^1\)
  – Using FY2011 traffic data, benefits at 43 top US airports can range from\(^2\):
    • 52k to 372k taxi hours reduction
    • $42 million to $300 million USD fuel reduction in FY2012 dollars

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NASA Research

- Develop a method for holding departure aircraft in ramp area (or holding spots)
  - Reduce taxi-out times
  - Reduce fuel consumption
  - Reduce emissions
  - No concession in runway usage
- Spot And Runway Departure Advisor (SARDA)
- SARDA in 2010: hold aircraft at spot
SARDA testing in 2010

- SARDA concept: hold departure aircraft at spot **tactically**
- Provide advisories to ATCT controllers
- Human in the loop simulations
  - Retired ATCT controllers
  - Human “psuedo-pilots”
  - Selected airport modeled after DFW airport, but several differences
  - 2 weeks of simulations, 56 runs
  - Varying traffic levels (Normal and Heavy)
  - Several advisory conditions
SARDA 2010 Results

• In heavy scenario, SARDA usage
  – Decreased average departure stops from 8.5 to 5.5
  – Decreased movement area departure delay by 66%
  – Decreased movement area departure fuel consumption and emissions by 38%

• Human factor observations
  – Heavy traffic increased perceived workload
  – Little impact of advisories on perceived workload. Expectation of workload alleviation offset by advisories differing from what they would do
  – “If metering required, would like the advisory”
NASA Research

- Develop a method for holding departure aircraft in ramp area (or holding spots)
  - Reduce taxi-out times
  - Reduce fuel consumption
  - Reduce emissions
  - No concession in runway usage

- Spot And Runway Departure Advisor (SARDA)
- SARDA in 2010: hold aircraft at spot
- SARDA in 2012: hold aircraft at gate collaboratively with airline.

SARDA-CDM
SARDA-CDM Assumptions

- Departure aircraft at gate – not directly under ATCT
- Ground controller can hold aircraft before taxiways
- Voice communication between cockpit and ATCT
- ASDE-X in movement area
- Aircraft position in ramp not known, but actual push-back times known
- Arrival aircraft – prediction of earliest active runway crossing
Planning Definitions

- **Planning window (PW):** how long each plan is. E.g. 15 minutes
- **Planning horizon (PH):** how soon is planning done. E.g. 30 minutes
- **Planning buffer (PB):** buffer time for airline response. E.g. 5 minutes
SARDA-CDM Walkthrough

Scheduled push-back
ABC101: 1502
ABC102: 1504
ABC103: 1507
SARDA-CDM Walkthrough

- **Scheduled push-back**
  - ABC101: 1502
  - ABC102: 1504
  - ABC103: 1507

- Current time
  - 1400
  - 1430
  - 1500
  - 1530
  - 1600
  - 1630

- PB: 5 min
- PH: 30 min
- PW: 15 min
SARDA-CDM Walkthrough

**Strategic Planning Component (SPC)**
- Strategic SARDA-CDM Scheduler

**Scheduled push-back**
- ABC101: 1502
- ABC102: 1504
- ABC103: 1507

- Flight restrictions (TMI)
- Flight details
- Airport config

Current time: 1400

1400 1430 1500 1530 1600 1630

PB 5 min  PH 30 min  PW 15 min

**ABC**
- ABC101
- ABC102
- ABC103
**SARDA-CDM Walkthrough**

**Stage 1**  
*Updated push-back*  
ABC101: 1504 (1502)  
ABC102: 1510 (1504)  
ABC103: 1508 (1507)

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**Strategic Planning Component (SPC)**  
**Strategic SARDA-CDM Scheduler**

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**Preferences**  
- Later push-back  
- Swaps

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**Airline**

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**Current time**

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**Timeline**

- PB: 5 min  
- PH: 30 min  
- PW: 15 min
**SARDA-CDM Walkthrough**

### Stage 1
**Updated push-back**
- ABC101: 1504 (1502)
- ABC102: 1510 (1504)
- ABC103: 1508 (1507)

### Strategic Planning Component (SPC)
- Strategic SARDA-CDM Scheduler

### Airline
- **Preferences**
  - Later push-back
  - Swaps

### Timeline
- PB: 5 min
- PH: 30 min
- PW: 15 min

**Current time**

**Timeline:**
- 1400: 0
- 1430: 0
- 1500: 0
- 1530: 0
- 1600: 0
- 1630: 0

**Airports:**
- ABC101
- ABC102
- ABC103
SARDA-CDM Walkthrough

Stage 2
Updated push-back
ABC101: 1504 (no change)
ABC102: 1510 (no change)
ABC103: 1508 (no change)

Strategic Planning Component (SPC)
Strategic SARDA-CDM Scheduler

Airline

1400 1430 1500 1530 1600 1630
PB 5 min PH 30 min PW 15 min

Current time
**SARDA-CDM Walkthrough**

**Stage 2**
*Updated push-back*
- ABC101: 1504 (no change)
- ABC102: 1510 (no change)
- ABC103: 1508 (no change)

**Strategic Planning Component (SPC)**

**Tactical Advisory Component (TAC)**
- Tactical SARDA-CDM Scheduler

**Time Line**
- PB: 5 min
- PH: 30 min
- PW: 15 min

**Current Time**
- 1400
- 1430
- 1500
- 1530
- 1600
- 1630

**Updated back**
- ABC101: 1504 (no change)
- ABC102: 1510 (no change)
- ABC103: 1508 (no change)
SARDA-CDM Walkthrough

Strategic Planning Component (SPC)

Agreed push back times

Tactical Advisory Component (TAC)

Tactical SARDA-CDM Scheduler

1400 1430 1500 1530 1600 1630

PB 5 min PH 30 min PW 15 min

Current time
SARDA-CDM Walkthrough

**Actual push-back**
- ABC101: 1507 (1504) late
- ABC102: 1500 (1510) early
- ABC103: 1508 (1508) on-time

10 sec update of all aircraft positions

**Strategic Planning Component (SPC)**

Agreed push-back times

**Tactical Advisory Component (TAC)**

Tactical SARDA-CDM Scheduler

PB: 5 min  
PH: 30 min  
PW: 15 min

1400 1430 1500 1530 1600 1630

Current time
SARDA-CDM Walkthrough

**Actual push-back**
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Strategic Planning Component (SPC)

Agreed push-back times

Tactical Advisory Component (TAC)

Tactical SARDA-CDM Scheduler

ATCT Advisories

1400 1430 1500 1530 1600 1630

Current time
Actual push-back
ABC101: 1507 (1504) late
ABC102: 1500 (1510) early
ABC103: 1508 (1508) on-time

10 sec update of all aircraft positions

Strategic Planning Component (SPC)

Agreed push-back times

Tactical Advisory Component (TAC)

Tactical SARDA-CDM Scheduler

ATCT Advisories

Current time
**Actual push-back**
ABC101: 1507 (1504) late
ABC102: 1500 (1510) early
ABC103: 1508 (1508) on-time

**10 sec update of all aircraft positions**

**Agreed push back times**

**ATCT Advisories**

**Strategic Planning Component (SPC)**

**Tactical Advisory Component (TAC)**

**Tactical SARDA-CDM Scheduler**

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**1400** **1430** **1500** **1530** **1600** **1630**

**Current time**
**Actual push-back**
ABC101: 1507 (1504) late
ABC102: 1500 (1510) early
ABC103: 1508 (1508) on-time

10 sec update of all aircraft positions

**Tactical Advisory Component (TAC)**

**Tactical SARDA-CDM Scheduler**

**Strategic Planning Component (SPC)**

Agreed push-back times

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Current time

1400 1430 1500 1530 1600 1630
CDM Compliance

• After gate push-back agreement, three potential outcomes:
  – On-time push-back
  – Early push-back: ground controller holds till allotted time
  – Late push-back
    • Compliance encouraged by public performance metrics based on agreed push-back times
    • If late, spot release by ground controller as early as possible, without affecting complying aircraft
SARDA-CDM Components and Uses

- Airline collaboration through SPC
  - Move delays from runway queue to gate
  - Fuel and emission reductions
  - Potentially better connections

- Ground controller advisory
  - Compliance to SARDA-CDM for early push-back

- Local controller advisory
  - Improve predictability for downstream (TRACON) integration of departure aircraft
  - Improve predictability of arrival aircraft movement on taxiways
Strategic or Tactical Gate Hold

- Dichotomy in providing delayed push-back to airline
  - If push-back to be delayed, knowing about it sooner might be better
  - Estimates of push-back readiness difficult to provide

- Tactical gate push-back through SARDA-CDM
  - Merge SPC and TAC, and use one version of SARDA scheduler
  - Effectively planning horizon = 0 minutes
  - Gate push-back readiness updates provided by airlines
  - Gate advisories updated and provided to airlines at frequent intervals
Tactical Gate-Hold Implementation

- SARDA-CDM implemented in SDSS-ATG closed loop
  - SDSS: a decision support tool to assist ATCT controllers
  - ATG: aircraft movement, provides flight tracks

- Real time simulation environment
  - Closed-loop: automatic aircraft movement by ATG using SDSS inputs (10 second updates); SDSS emulates controllers
  - Open-loop: ATG movement by pseudo-pilots based on controller instructions

- Open-loop used in human-in-the-loop studies
- Taxi speed uncertainty (12 to 17 knots)
Cases

• Baseline (base)
  • no metering
  • release from spot when possible
  • runway usage based on swapping heuristic, not first-come-first-served

• Advisory (adv): complete compliance with no push-back uncertainty

• Increasing push-back uncertainty
  – 30s, 60s, 120s, 180s
  – Positive only, delay in push-back
  – Early push-back held, late push-back could lead to throughput loss

• 2 scenarios, 1 hour each, 1.5x current day operations
• Each scenario and case run 10 times
No significant change in schedule delay
Taxiing Delay

Delay in ramp and active movement area

Even with increasing uncertainty in gate push-back, there is little increase in taxiing delay
Extra Fuel Used

Avg reduction per aircraft
50kg in scenario 1
150 kg in scenario 2
Cumulative Runway Usage
Cumulative Runway Usage

Cumulative runway usage, Scenario 2

Cumulative runway usage, Scenario 2

Cumulative runway usage, Scenario 2

Cumulative runway usage, Scenario 2
Cumulative Runway Usage

For the 2 scenarios tested, loss in runway usage with 180s push-back uncertainty not substantial
Research Questions

- Interface for airline inputs and ATCT
- Best planning horizon, window, airline input mechanism
- Policy issues (on-time performance metric)
- Attempts to game
- Scheduler design under uncertainty
- System effects
  - Taxi delay, fuel and emission benefits
  - Passenger connectivity
  - Disadvantages (e.g. throughput loss due to push-back uncertainty)
  - Predictability
Ongoing Research

- SARDA
  - Human in the loop simulations conducted in May 2012
  - Full tower simulation
  - Data analysis underway

- Exploring collaboration with
  - airline industry for field tests
  - FAA for integration in future surface CDM tools