Stochastic simulation of delay propagation
Improving schedule stability at Kenya Airways

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Purpose of the presentation

• Introducing research area

• Discuss the research
  – Model
  – Simulation and Validation
  – Application

• Present conclusions
Kenya Airways connects Africa

Basics of a Hub and Spoke Network

- Introduction
- Model
- Simulation
- Validation
- Application
- Conclusions
Domino effect of delays

- **Primary Delay**: Amsterdam - Nairobi

**Reactionary Delays**
- **Due to Aircraft**: Nairobi - Amsterdam
- **Due to Transfer Passengers**: Nairobi - Brazzaville, Gaborone, Maputo

Delay severity = 4
High share of reactionary delays

- Primary: 49%
- Reactionary: 51%
- 2% Crew
- 20% Passengers
- 78% Aircraft

Analysis for Kenya Airways
Period: Sep 2010 – Sep 2011
Research question

How can the absorption robustness be simulated for a proposed seasonal flight schedule in terms of aircraft and passengers, and how can this be used to aid Kenya Airways in increasing schedule stability?
Overview research

Model

Simulation

Validation

Application

Introduction
Model overview

- Departs if Aircraft and Passengers are ready
- Continues till all delay is absorbed

1. Block-time
2. Turnaround-time
3. Passenger Connections
1. Block-time

- Approximation depends on:
  - Route and direction
  - Aircraft type
  - Season

Nairobi – Lilongwe, Boeing 767-300 (summer)
Block-time Analysis Module

• Dashboard to measure and adjust scheduled times
2. Turnaround-time

- Minimum Turnaround-time depends on Aircraft Type
- Dataset: A/C Reactionary delayed flights

Boeing 767-300
3. Passenger Connections

- Critical connection
- Minimum Connection-time depends on # pax
- Dataset: Load Reactionary

Number of passengers
Downstream frequency

Introduction  Model  Simulation  Validation  Application  Conclusions
Flight delay severity simulation

• Illustrated for flight KQ0550 to Brazzaville
Flight delay severity simulation

• Simulating the likely outcomes per delay

30 minute delay for flight KQ0550 to Brazzaville:
Delay Severity Curve

• Visualize the possible impact for a range of delays

Flight KQ0550 to Brazzaville:
Delay Severity Curve

• Visualize the possible impact for a range of delays

Flight KQ0550 to Brazzaville:

![Graph showing delay severity curve with axes labeled: Delay Severity on the y-axis and Length of primary delay (min) on the x-axis. The graph includes lines and shading representing simulation and average values.]
Empirical validation

- Overlay with historical data to validate findings
  - Due to aircraft rotations
  - Due to pax connections
  - Complex combination

Flight KQ0500 to Douala
Empirical validation

• Overlay with historical data to validate findings
  - Due to aircraft rotations
  - Due to pax connections
  - Complex combination

Flight KQ0555 from Kinshasa
Empirical validation

- Overlay with historical data to validate findings
  - Due to aircraft rotations
  - Due to pax connections
  - Complex combination

Flight KQ0702 from Harare to Lusaka
Application of simulation

- Compare flights
  - Improve Critical Flights
    - Comparative study against Baseline Schedule
Compare Flight Robustness

- Expected Delay Severity = 1.03
- Weighted average according to $P(\text{delay})$

Flight KQ0550 to Brazzaville
Case Lagos: Analysis of Critical Flight

High expected delay severity of 2.1 to 2.4

- Lower regions due to Block-time
- Higher regions due to Pax Connectivity

19% Inbound Block-time confidence
Case Lagos: Analysis of Critical Flight

High expected delay severity of 2.1 to 2.4

- Lower regions due to Block-time
- Higher regions due to Pax Connectivity

Inter-locked passenger connectivity with Dubai

Flight KQ0532 to Lagos
Case Lagos: Proposal

Solution:

1. Increase rotation
2. Alternate connectivity
Case Lagos: Proposal

Implementation:

By February 2012 due to Aircraft availability of the Boeing 767's

KQ0352 to Lagos
Base

KQ0352 to Lagos
Proposal
Overall improvements made

• Aggregated Expected Delay Severity: from 192 to 157
Academic conclusions

• Extended traditional Delay Propagation model:
  – Passenger connectivity
  – Stochastic Estimation

• Introduced the Delay Severity Curve

• Validation with empirical data

• Expected Delay Severity as metric
Deliverables for Kenya Airways

• Block-time analysis module
  – Implemented per Aug 2011
  – Advised on 27 of 125 flights, implemented per Sep 2011

• The stochastic simulation of delay propagation
  – Prototyping phase
  – Implementation requires automated database connections
  – Alternative flight timing for Lagos due Feb 2012
Directives for future research

• Extension to a generic simulation (Discrete Event)
• Integration of Cost Reference Model (Cook, 2011)
• Combine into an optimization research
• Incorporate Passenger Connection Saver