Robust Scheduling and Flight Delays

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Outline

- Aircraft and passenger delays
- Delay propagation
  - Role of aircraft rotations
  - Role of flight schedules
- Optimization models to minimize delay propagation and its impact on passengers

DOT On-Time Performance Metric

- Sources of passenger delays
  - Cancellations
  - Missed connections
  - Delayed flight
- DOT 15-minute on-time performance metric
  - Does not include passenger delays resulting from cancellations or from missed connections
  - ➢ An inadequate measure of passenger delays

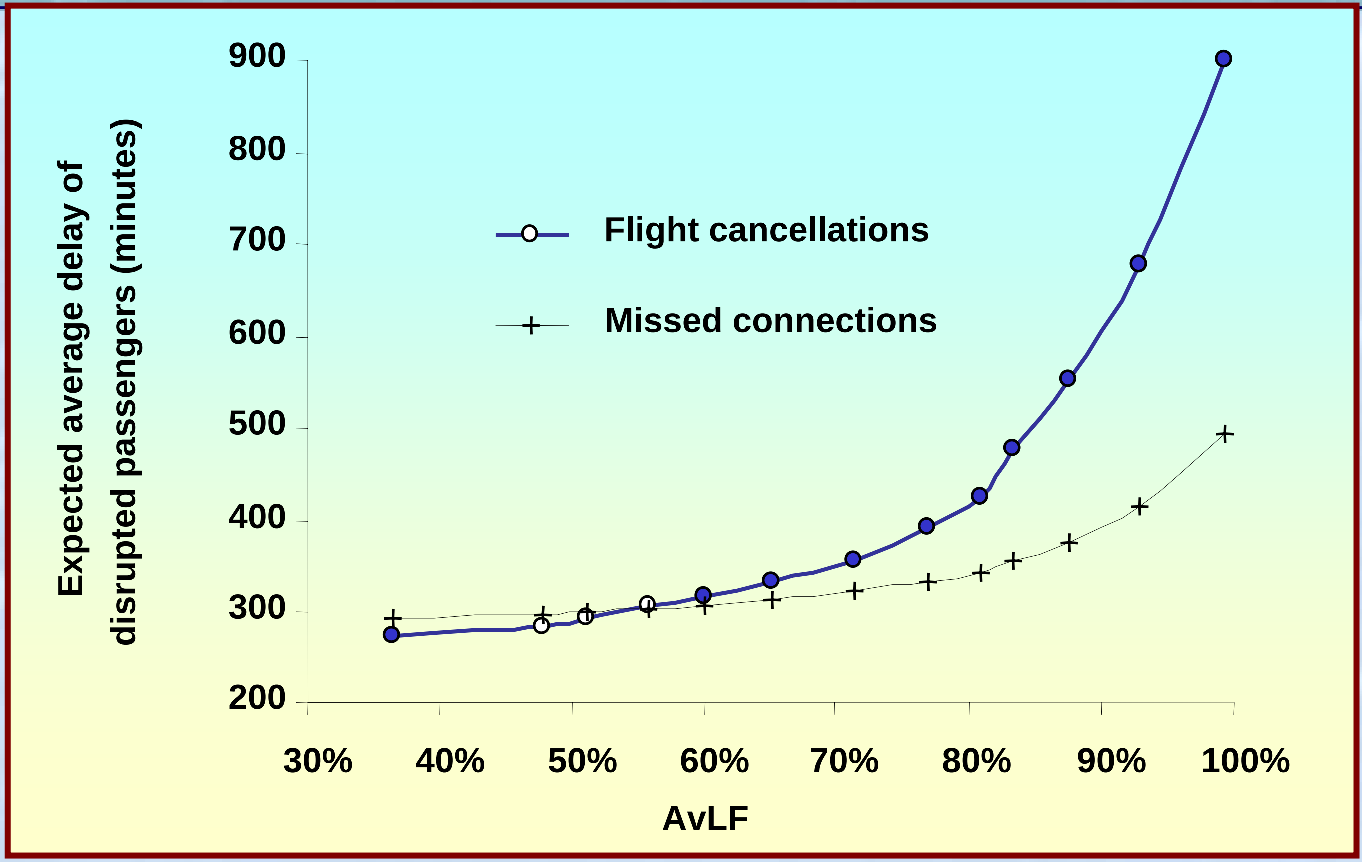
Comparison of Passenger and Flight Delays

	Average delay (minutes)
Passengers	25.6
Flights	15.4
Ratio	166%

Passenger	Average delay	% Passengers	% Total passenger delays
Disrupted	303 minutes	3.2%	39%
Non-disrupted	16 minutes	96.8%	61%

Passenger	Average delay	% disrupted passengers	% of disrupted passenger delays
Same day (SD)	185 minutes	78%	48%
Overnight (OV)	721 minutes	22%	52%

The Effect of Load Factor on Passenger Delay



Passengers, disrupted because of a flight cancellation, become increasingly more difficult to re-accommodate as load factors increase

What Can Be Done?

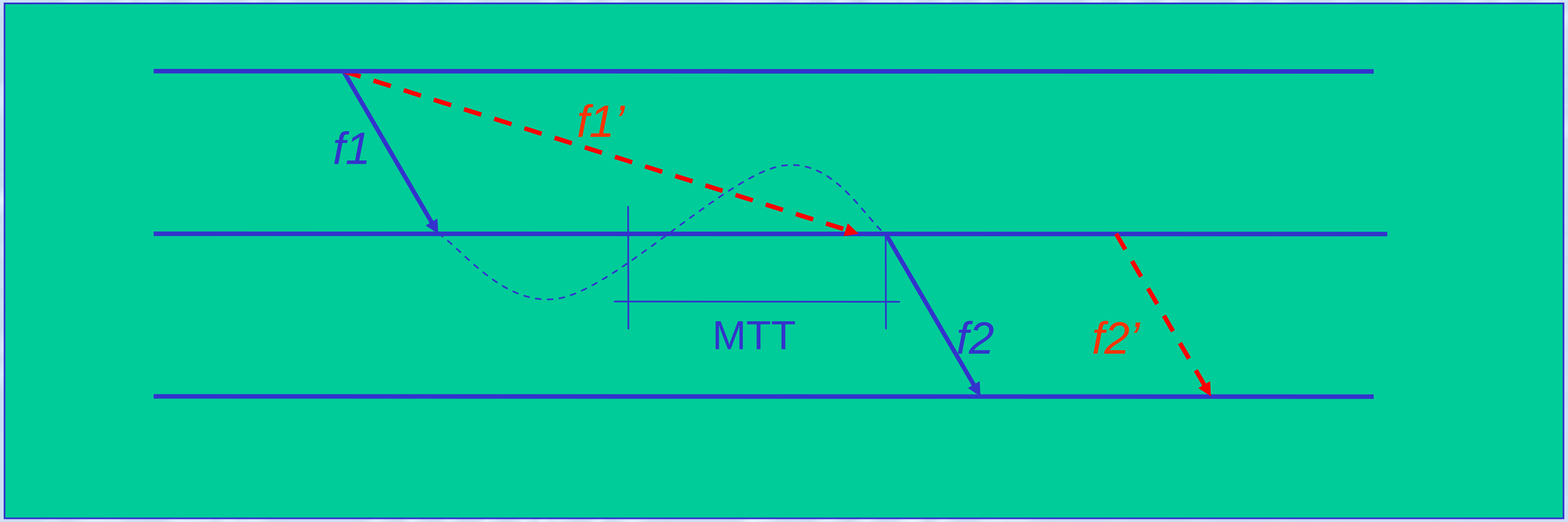
- Many things…
- One approach: create schedules less impacted by and/ or easier to recover from disruptions
  - Robust aircraft routing and scheduling
    - Reduce the propagation of delays by re-designing aircraft routings
    - Reduce the number of passenger misconnections by adjusting departure times so that passenger connection times are correlated with the likelihood of a missed connection (disruption)
      - Add connection slack where it is need most

Robust Aircraft Routing and Scheduling

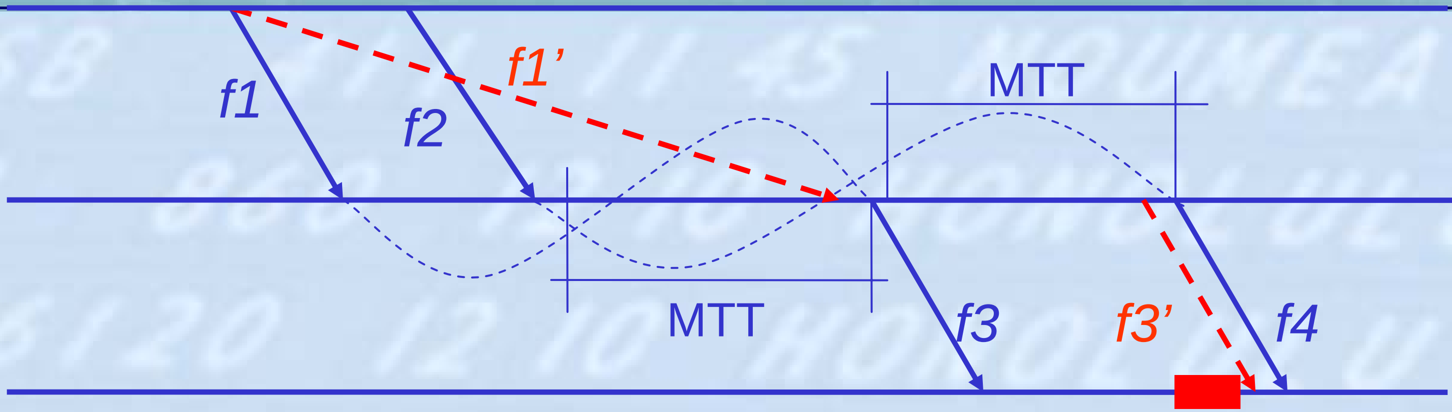
- Objective
  - Reduce the propagation of delays by re-designing aircraft routings
- Solution Approach
  - Formulate and solve maintenance routing model that minimizes the expected propagation of delays subject to maintenance feasibility

Delay Propagation

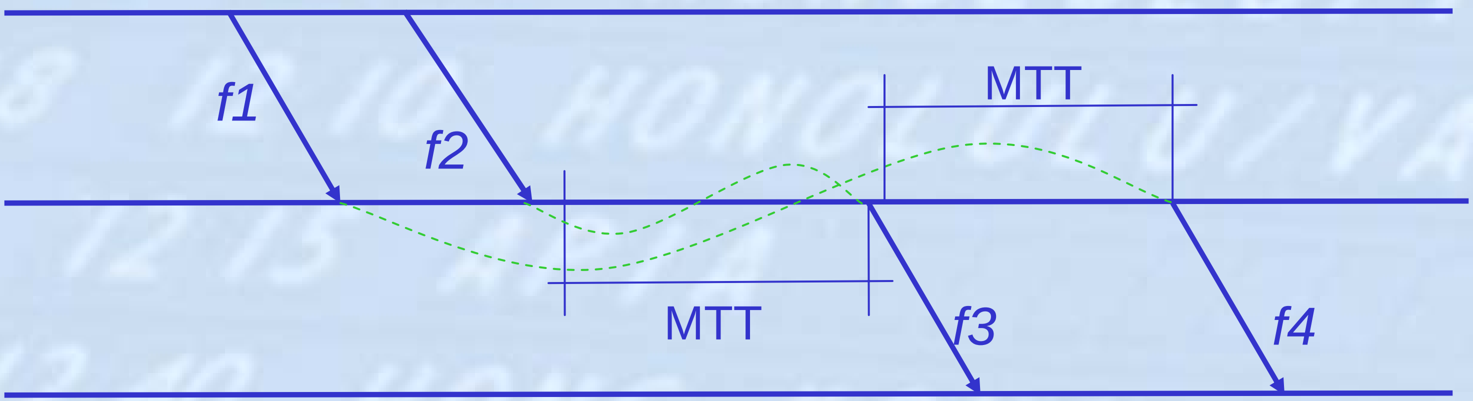
- Arrival delay might cause departure delay for the next flight leg that is using the same aircraft if there is not enough slack between consecutive flight legs
- Delay propagation might cause downstream schedule, passenger and crew disruptions (especially at hubs)



Dampening Delay Propagation through Routing



Original routing



New routing

Computational Results

Test Networks

Network	Num of flights	Num of strings
N1	20	7,909,144
N2	59	614,240
N3	97	6,354,384
N4	102	51,730,736

- **Model Building and Validation**

July 2000 data → Model → Routes → Aug 2000 data

- **Propagated delays (August 2000)**

Network	Old PD	New PD	PD reduced	% of PD reduced
N1	6749	4923	1826	27%
N2	4106	2548	1558	38%
N3	8919	4113	4806	54%
N4	14526	9921	6940	48%
Total	34300	21505	15130	44%

Results - Delays

Total delays and on-time performance

	Total delay			on-time performance		
	>15 min	>60 min	>120 min	15 min	60 min	120 min
Old	22.3%	7.9%	2.9%	77.7%	92.1%	97.1%
New	20.7%	6.9%	2.6%	79.3%	93.1%	97.4%

Passenger misconnects

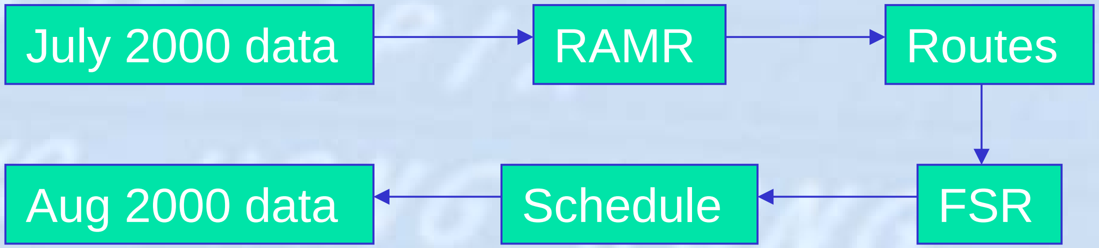
Network	Total num of D-pax	D-pax reduces	D-pax reduced (%)
N1	986	147	14.9%
N2	1070	79	7.4%
N3	1463	161	11.0%
N4	3323	355	10.7%
Total	6842	742	10.8%

Flight Schedule Re-Timing

- **Objective**
  - Reduce the number of passenger misconnections by adjusting departure times so that passenger connection times are correlated with the likelihood of a missed connection (disruption)
    - Add connection slack where it is need most
- **Solution Approach**
  - Derive distributions from historical data for number of passengers disrupted for each connection
  - Formulate and solve re-timing model that minimizes the number of disrupted passengers

Computational Results

- **Network**
  - We use the same four networks, but add all flights together and form one network with total 278 flights.
- **Model Building and Validation**



Computational Results

- **Estimated reduction (30 minutes MCT) in total passenger delays:**
  - 20% (30 minute time window)
  - 16% (20 minute time window)
  - 10% (10 minute time window)

Time window	Tot num of D-pax	Output	D-pax reduced	Improve (%)
±15min(7 copies)	17,459	10,899	6,560 (37.6%)	
±15min(31 copies)	17,459	10,865	6,594 (37.8%)	0.52%
±10min(5 copies)	17,459	12,070	5,389 (30.9%)	
±10min(21 copies)	17,459	12,056	5,403 (30.9%)	0.26%
±5min(3 copies)	17,459	14,069	3,390 (19.4%)	
±5min(11 copies)	17,459	14,058	3,401 (19.5%)	0.28%

Conclusions

- Robustness considerations-
  - Same optimization techniques, new models and objectives, potentially significant impacts without increased planned costs
- Much more that can be done with robustness modeling and optimization, in many areas of schedule planning and recovery