Hot Spot Identification & Mitigation at Strategic Level by Small Changes in Aircraft Time of Arrival at Junction

Mr. Dany Gatsinzi
Prof. Francisco Javier Saez Nieto
Dr. Irfan Madani

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www.cranfield.ac.uk

Research Motivation

- **Challenge**: Tactical actions taken by the Air Traffic Controllers to resolve A/C potential conflicts are the main bottleneck of the current ATM system.

- **Solution**: Trajectory Based Operations (TBO) Concepts : Trajectory management at Strategic level.

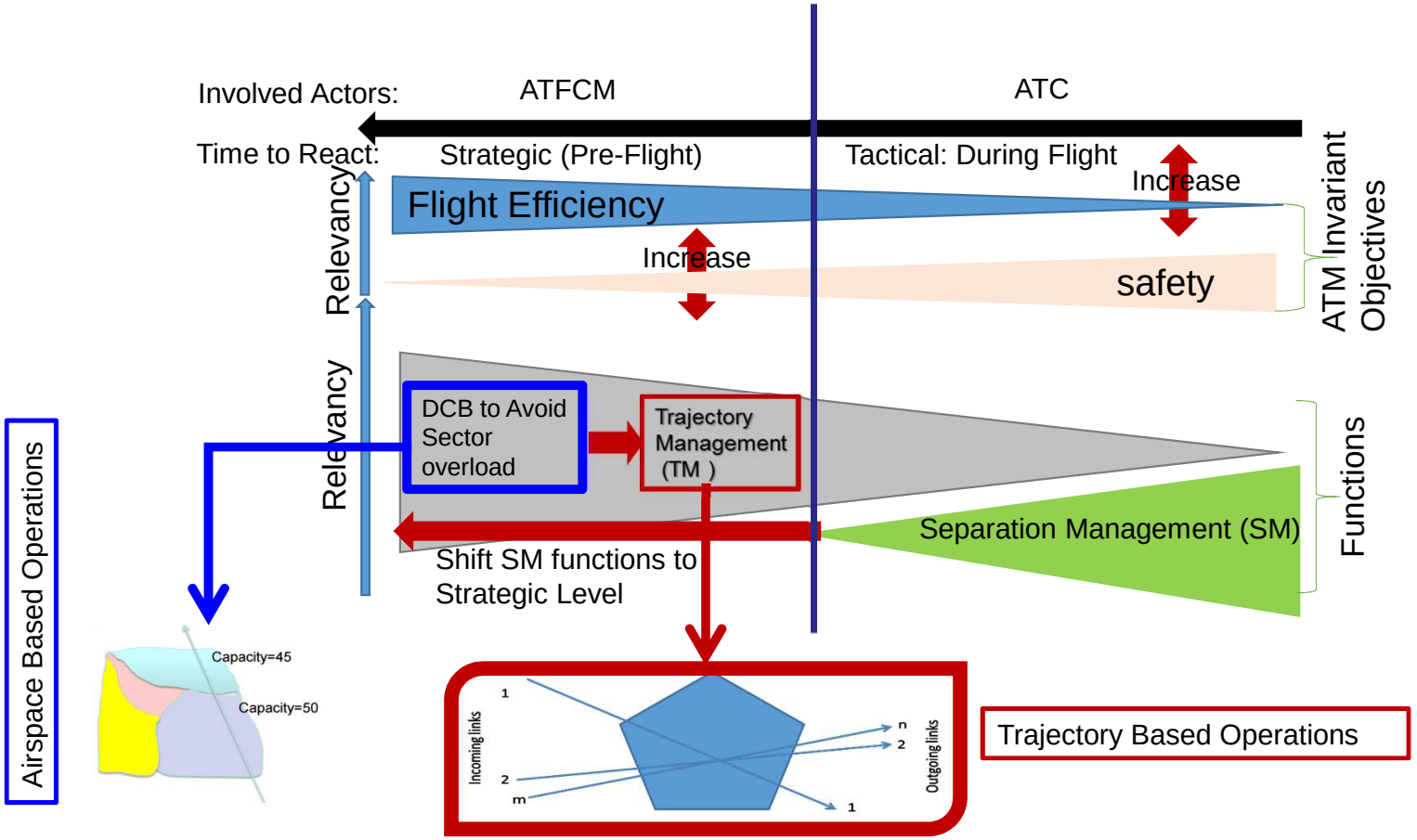
Purpose of the Research

- To reduce the probability of ATCO's tactical interventions at strategic level.

- Propose a new ATFCM metric for demand measure in order to change the current airspace capacity limiting factor, in line with TBO.

Background

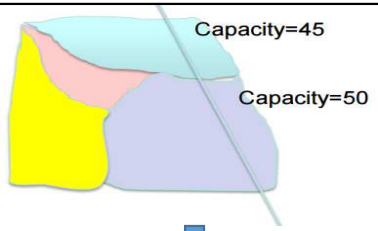
- **Strategic Management Vs. Tactical Management**



Background

❑ Paradigm Shift :Airspace Based Ops to Trajectory Based Ops

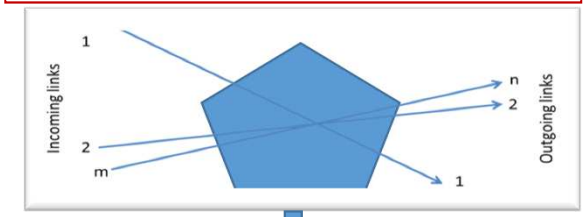
Sector/Airspace Based Operations



- ❑ **Strategic level**: Trajectory Incompatibilities (Potential conflicts)are not known in advance
- ❑ **Tactical Level**: It is up to the ATCO to detect and resolve any potential conflicts

- ❑ **Airspace Capacity**: Limited by ATCO tactical interventions to resolve potential conflicts in a sector

Trajectory Based Operations (TBO)

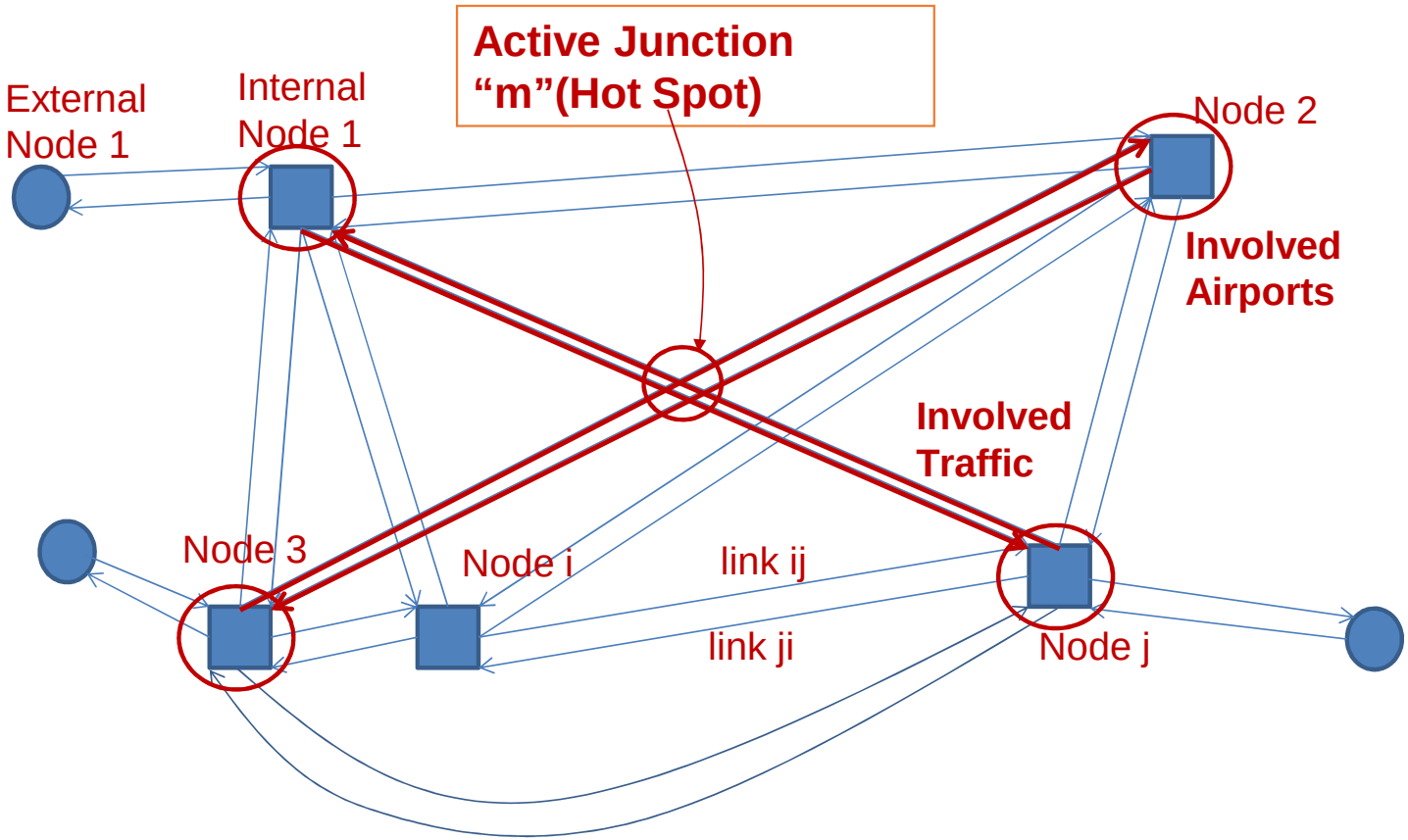


- ❑ **Strategic level**: Trajectory Incompatibilities are detected & mitigated
- ❑ **Tactical Level**: Potential conflicts are radically reduced, ATCO Monitors the traffic flow

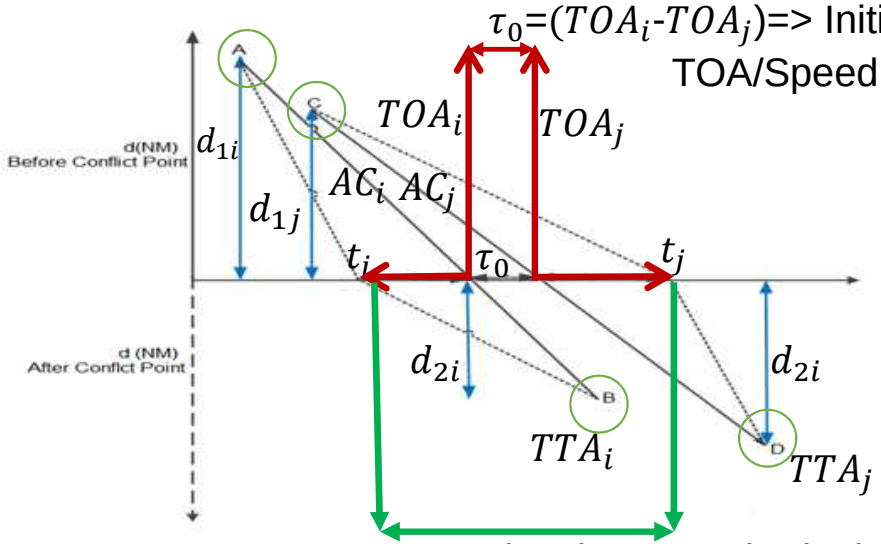
- ❑ **Airspace Capacity**: Is not Limited by ATCO tactical interventions in a sector

Proposed Approach

❑ Airspace Topology



Proposed Approach



τ_0=(TOA_i-TOA_j)=> Initial separation at Junction before TOA/Speed Changes are applied

τ_p=(t_i-t_j)=> Required Minimum safe time separation at Junction

LP Optimisation Tool:

- Minimise total amount of Distance-weighted speed changes: $J = \sum_i \sum_m \delta V_{im}^{m+1} \cdot d_{im}^{m+1}$
- Speed changes are bounded bellow a given threshold : $\delta V_{im}^{m+1} \leq 0.0X.V_{im}^{m+1}$.
- Departure & TTA are maintained as constraints.
- The Initial Time Separation at Junction between any two successive aircraft before speed/TOA changes are randomly generated within a given time interval " τ_0".
- New TOA will be issued by NM to the Aircraft to be included in the new RBT.

Proposed Approach

- **How to quantify "τ_p" in the presence of uncertainty in A/C's Time of Arrival at Junction (TOA), that minimises ATC tactical Interventions?**

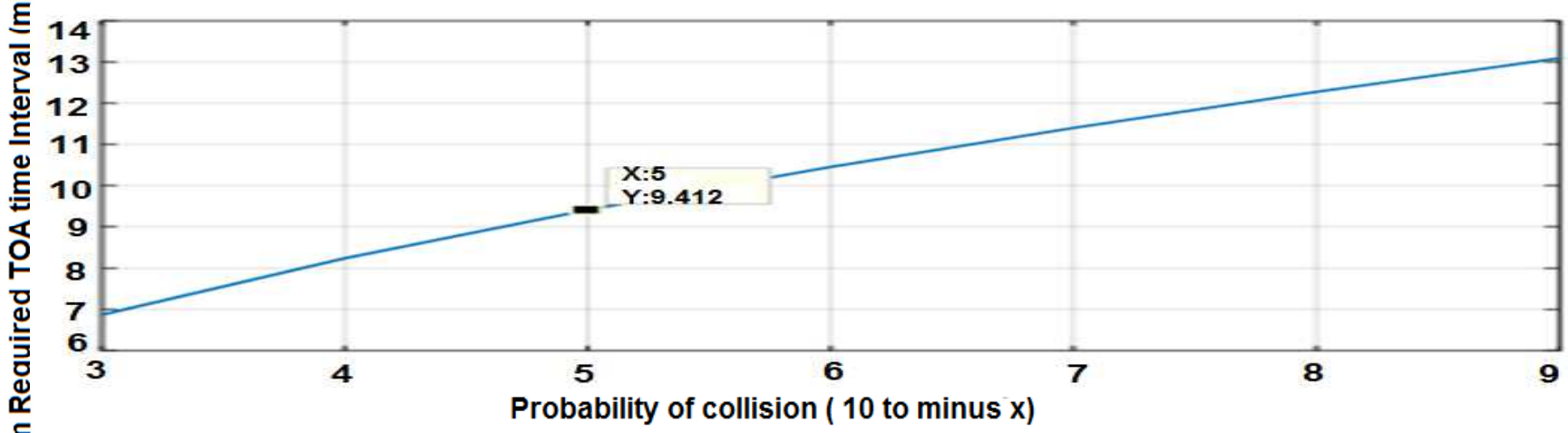
- Deviations in the A/C Time of Arrival (TOA) at Junction

Uncertainty at the junction	**Standard deviation specifications & Required Operation/performance conditions**	
	A/C TOA standard deviation specification	Required condition
A/C Lateral deviation	$\sigma_{T1i,j} = \sqrt{2} \times \frac{\sigma_{LD}}{V_{i,j} \times \sin(\alpha_{ij})} = 30$ sec	Crossing angle $\alpha \geq 20^0$ and RNP1 Flight Speed > 200kt
Initial time deviation	$\sigma_{T2i,j} = 1$ min	SESAR Targets & current research efforts
Along-track time deviation	$\sigma_{T3i,j} = \frac{d_{i,j}}{V_{i,j}^{\ 2}} \times \sigma_{Vi,j} = 1$ min	A/C is CTA equipped
Combined Time Deviation	$\sigma_T = 1.5$min	Combination of the above conditions

Proposed Approach

❑Minimum Time Separation (τ_p) & Probability Of Collision (PC)

$$\tau_p = \sqrt{-2(\sigma_{Ti}^2 + \sigma_{Tj}^2) Ln[P_C \times \sqrt{2\pi(\sigma_{Ti}^2 + \sigma_{Tj}^2)}]}$$



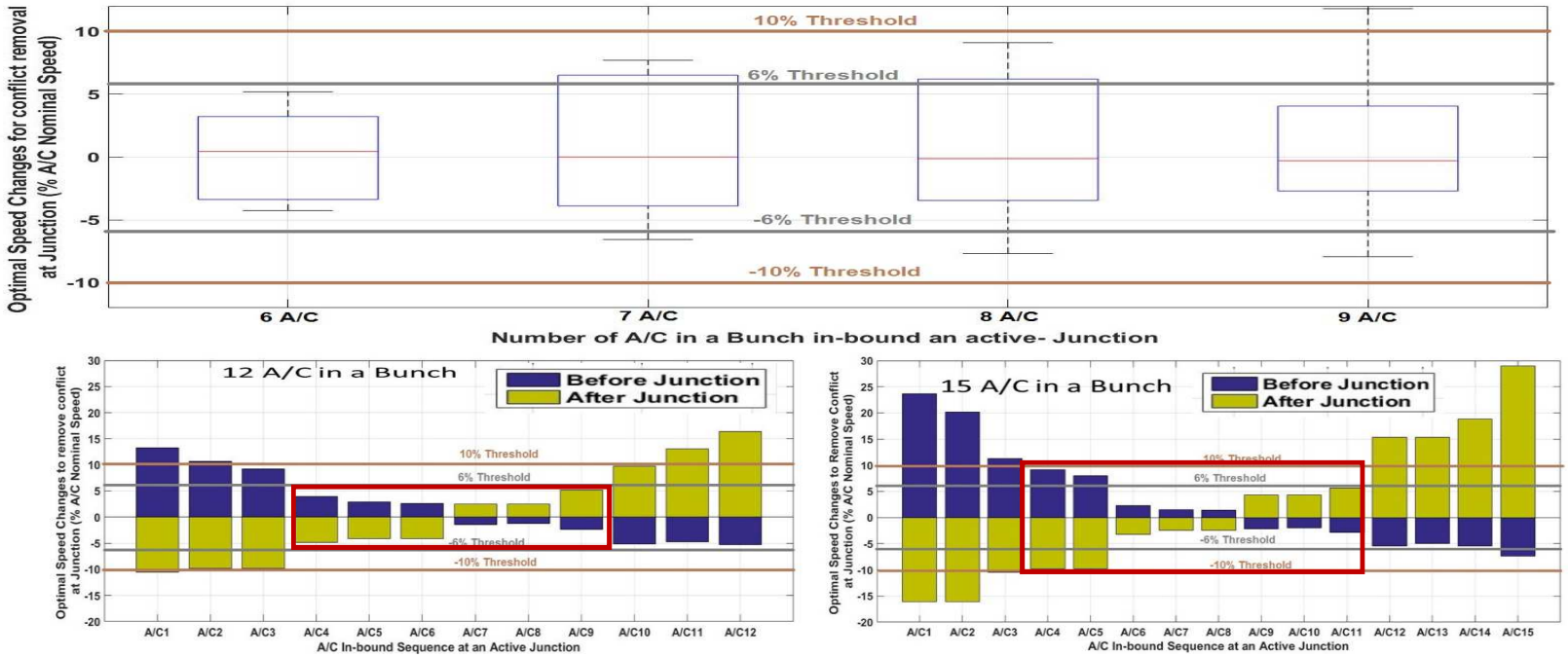
- ❑ minimum safe separation Interval at Junction: $\tau_p \approx 9$ minutes
- ❑ Probability of collision : PC=10^{-5}
- ❑ Junction inbound capacity QI_m=1/ τ_p = 6 A/C per Hour

Example Solutions

❑Number of A/C in a Bunch that Can be Realistically De-conflicted

Bunch => Sequence of two or more aircraft inbound an active junction for a given period of time

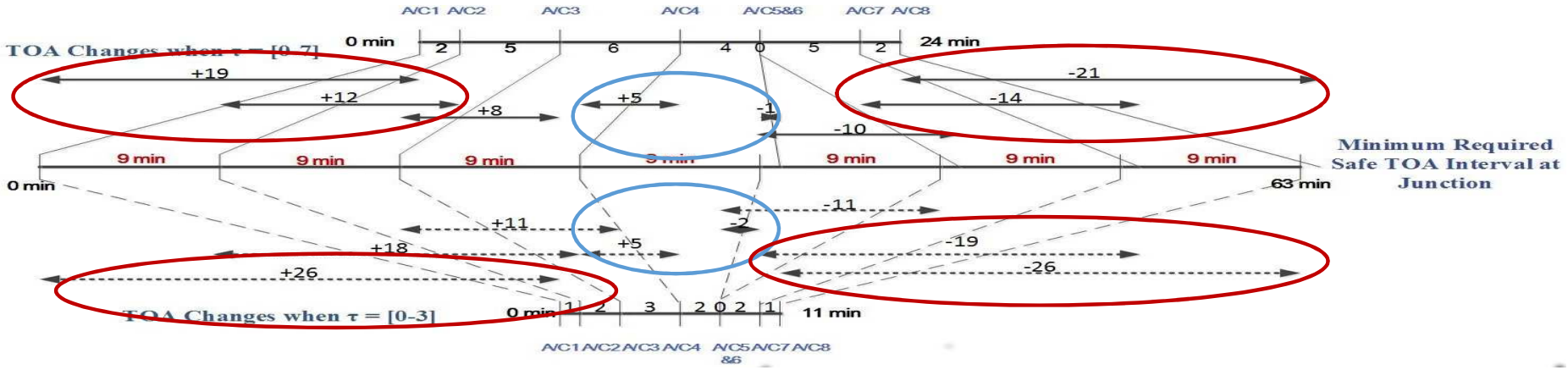
τ_0 **=[0 9**]=> All in bound traffic in a Bunch are initially in conflict

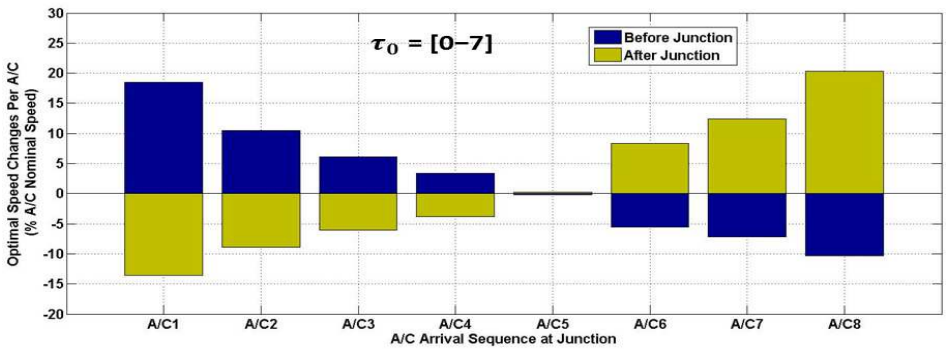


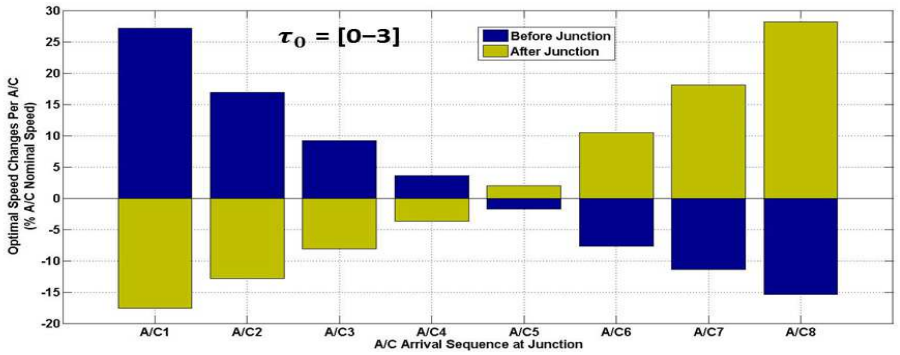
Speed changes per aircraft for 12A/C and 15 A/C in a bunch

Example Solutions

- Monotonic Increase of Speed/TOA changes when τ_0 < [0 9]

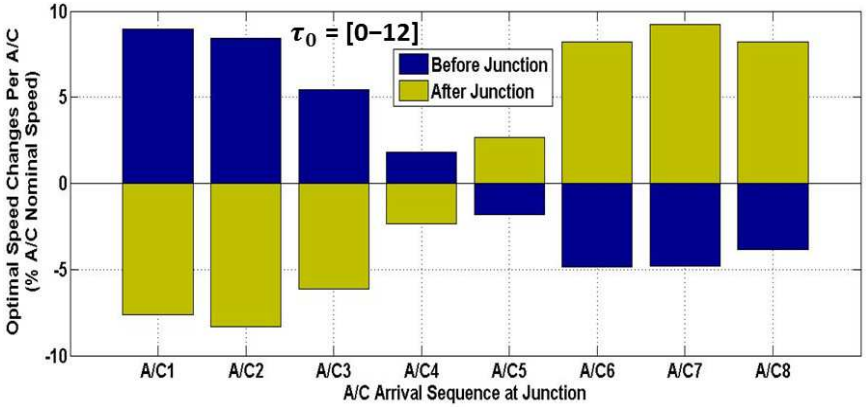


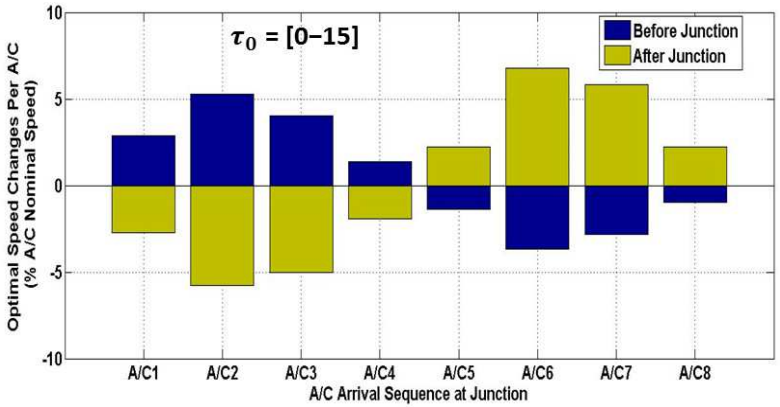




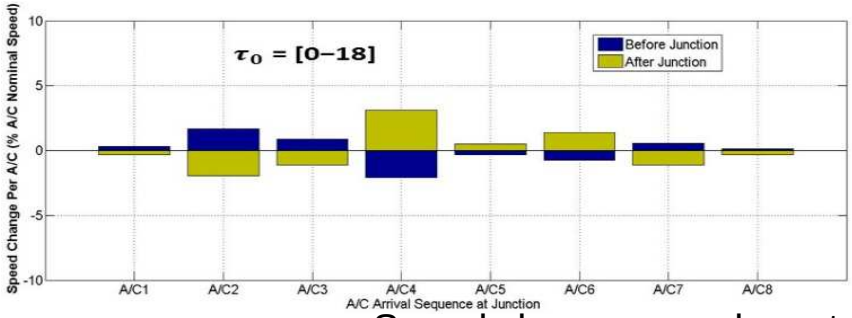
Example Solutions

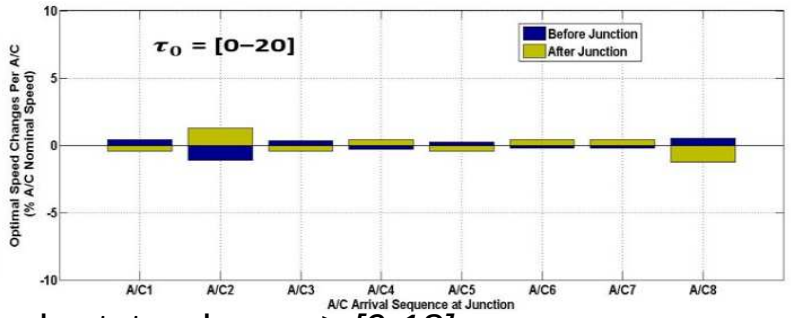
- Modulation of Speed/TOA Changes & Steady State





Oscillated behavior of speed changes when $\tau_0 \geq$ *[0-9]*





Speed changes reaches steady state when $\tau_0 \geq$ *[0-18]*

Assumption: Free-Routing is Assumed

Conclusions

- New ATFCM metric for demand measure based on Hot Spot identification & mitigation at strategic level is proposed.
- The minimum safe separation interval at junction: $\tau_p \approx 9$ minutes that gives a probability of collision of PC=10^{-5} is established.
- The mitigation actions are based on establishing new TOA at Junction computed using a basic LP optimisation.
- Monotonic increase of TOA/Speed changes for first and last aircraft in a bunch is changed by establishing specific traffic demand and operational conditions.
- Conditions under which TOA/Speed changes reach the stable state are established.
- **Further Work**: Run the model based on a larger actual airspace structure such as ECAC structure

THANK YOU