SATURN

STRATEGIC ALLOCATION OF TRAFFIC USING REDISTRIBUTION IN THE NETWORK

Modulation of en-route charges to redistribute traffic in the European airspace

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Consortium

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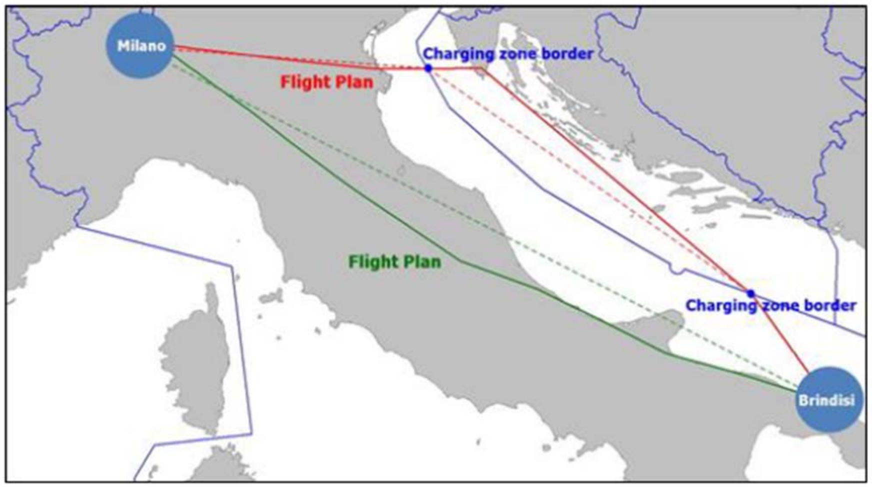
SATURN's Objective

- Propose and test realistic ways to use market-based demand-management mechanisms to redistribute air traffic in the European airspace, at the **strategic** level

- Today hardly any demand management action is undertaken prior to the day of operations (tactical level), resulting in application of very costly and likely rather inequitable measures
  – Access to the congested airspace is based on administrative rules (FPFS)
  – Airlines' willingness to pay is not taken into account for such access

Pricing is an option

- From *PRB Annual monitoring Report 2012, Volume 1, European overview and PRB recommendations, Section 3.2*, 13/09/2013



- For an aircraft weighing 80 metric tonnes, the price per kilometre (July 2013) is €1.00 in Italy and €0.53 in Croatia. **The longer route (through Croatia) is therefore €177.19 cheaper**

- Such a situation exposes the risk of possible unintended consequences of the current rules
  - They might constitute an incentive for airspace users to file longer routes with a detrimental effect on the horizontal flight efficiency indicator
  - They might create cost competition based on Unit Rates, in order to attract traffic

Modulation of ANS Charges

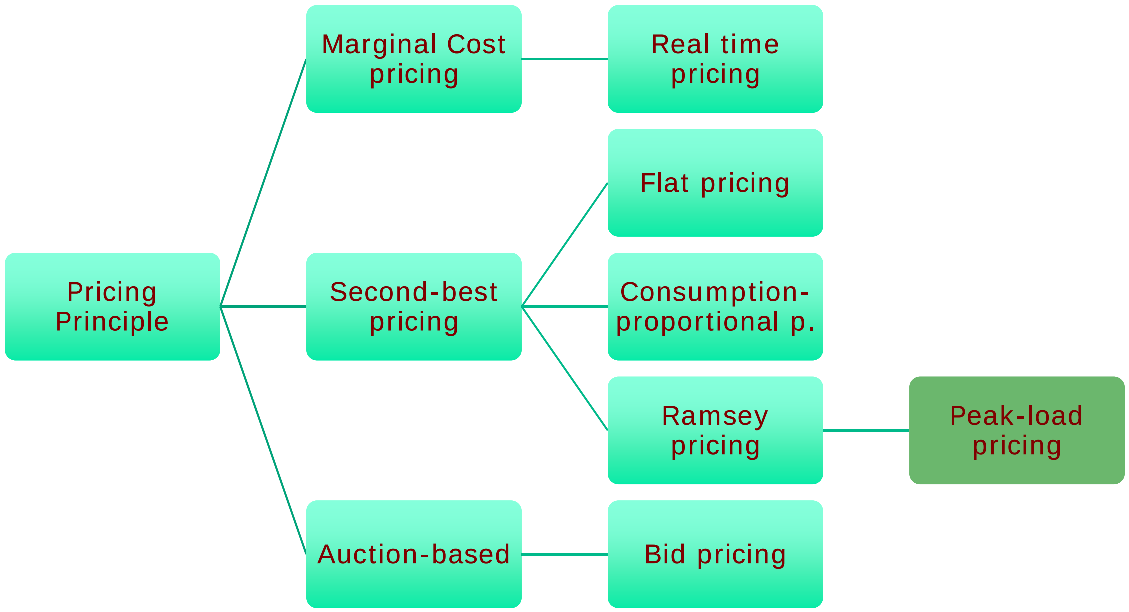
- COMMISSION IMPLEMENTING REGULATION (EU) No 391/2013 of 3 May 2013 – Article 16
  - Member States […] may […] reduce the overall costs of air navigation services and increase their efficiency, in particular by modulating charges **according to the level of congestion of the network in a specific area or on a specific route at specific times**. […]
  - **The modulation of charges shall not result in any overall change in revenue for the air navigation service provider**. Over- or under recoveries shall be passed on to the following period.
  - **The modulation of air navigation charges means a variation of the en route charge** and/or the terminal charge calculated on the basis of the provisions of Articles 11 and 12.

Pricing mechanisms

- **Pure pricing**
  - **Traffic redistribution depends on monetary aspects only**
  - **Also next presentation (Uni. Belgrade)**
- Hybrid pricing
  - It combines quantity- and price-based allocation instruments, like credits or permits
- **Deterministic**
  - **All data and parameters are known in advance**
- Uncertainty
  - Demand and capacity uncertainty, user irrationality, imperfect knowledge in terms of route selection

Pricing policies in network industries

- Congestion charges in urban road networks;
- Peak load pricing in public transports;
- QoS pricing in telecommunications;
- Locational Marginal Prices in electricity wholesale;
- Credit-based pricing for electricity retail.



Peak-Load Pricing (PLP)

- Assumptions:
  - Peaks in demand are periodic in time and location (and therefore predictable).
  - Demand has some degree of elasticity towards time and/or location of service consumption (and therefore sensitive to its price).
- Action:
  - Times and/or locations where a peak in demand is expected are assigned a higher rate than sectors and times expected to be off-peak.
- Objective:
  - Reduce the amount of shift on the network.
  - Shift. Difference between the requested (from AUs) and assigned (from the CP) departure or arrival time (Dep. Shift or Arr. Shift).
- Expectations:
  - Part of the peak demand will deviate their travel/consumption choice to a cheaper option.

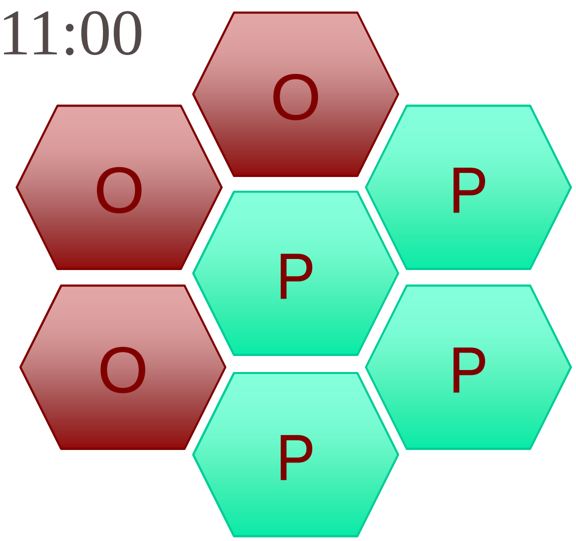
Operational environments

- Centralised
  - Prices (or rates) set and modulated by a central planner
- Decentralised
  - ANSPs (or FABs) act independently. The central planner has a limited role (e.g., acting as a regulator in disputes between ANSPs).
  - Each ANSP (or FAB) is responsible for setting and modulating its own rate
- Airlines' requests accommodated to the maximum possible extent

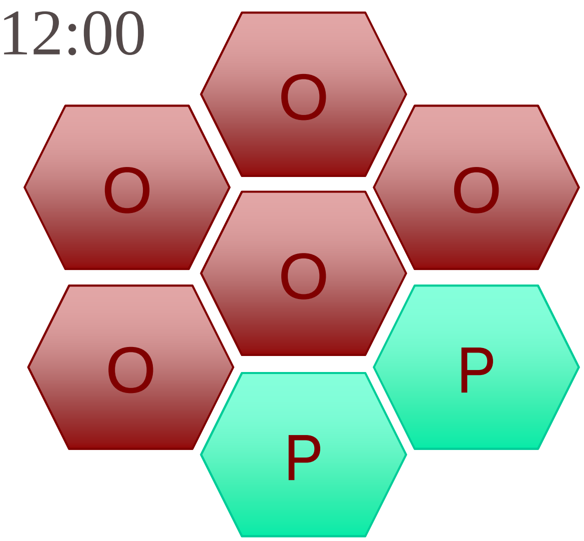
Peak analysis

- Each ANSP has a unique Peak/Off-peak set of rates;
- Peak times and locations are known in advance (estimated by analysing past traffic);
- Hourly sector load factor (LF) ratio: HourlyEntryCount / Capacity;
- If LF >= PeakThreshold: assign Peak (P); otherwise: assign Off-peak (O).

10:00-11:00

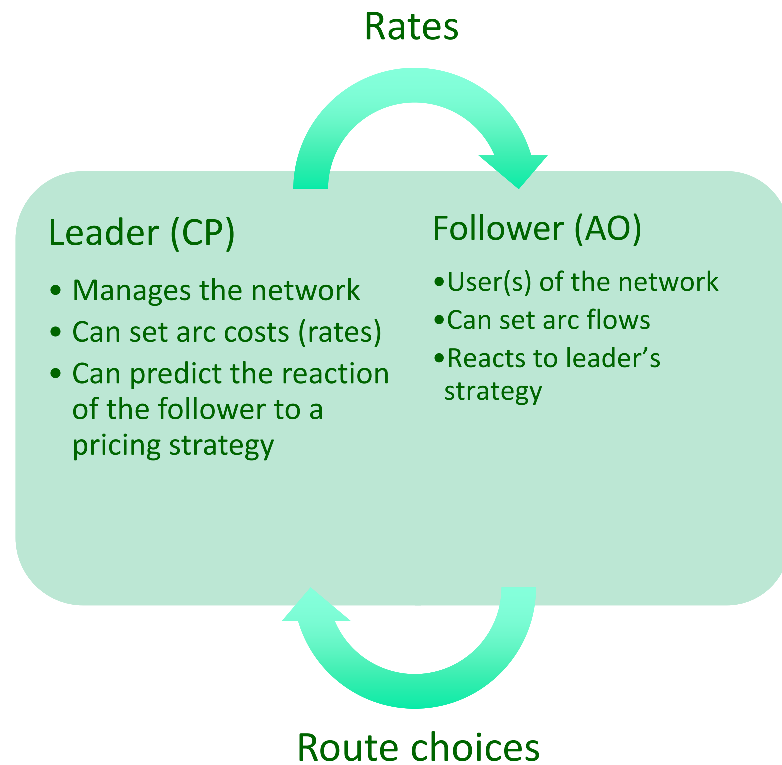


11:00-12:00



Centralised PLP (CPLP)

- A central planner (CP) sets peak and off-peak rates on the whole network.
- Such rates should guarantee that:
  - **Global schedule shift ("strategic delay") and capacity violations are minimised**
  - ANSPs are able to recover their costs for providing ANSs.
  - AOs are able to perform flights avoiding imbalances between the amount of traffic and available airspace capacity.
- Each AO chooses the cheapest route for each of its flights.



Our formulation captures the trade-off between the two competing objectives of CP and AOs by modelling it as a Stackelberg game.

- Bi-level linear programming.
- Hard to solve with exact methods.
- Two meta-heuristic approaches: Genetic Algorithms and Coordinate-wise Descent

Assumptions (I)

- ***Fixed demand.*** A fixed number of flights between any airport pair in the network.
  - The intention of the proposed pricing mechanism is not to scale down the total demand.

- ***Infrastructure capacity constraints known in advance*.**
  - Nominal sector and airport capacity, without variations introduced by regulations.
  - Pre-defined airspace sectorisation.

- ***Finite set of possible (reasonable) 4D trajectories*** for each
  - Origin/Destination/Aircraft triple: users can select a route from a set of pre-determined routes (derived from actual traffic).

Assumptions (II)

- ***Aircraft Operators (AOs) are rational decision makers***. All AOs are assumed to choose the cheapest route and may therefore switch to a different route whenever the conditions (i.e., unit rate) change.

- ***Revenue neutrality***. ANSPs revenues are to be kept as close as possible to the cost of ANS provision.

- ***Heterogeneous demand***, in terms of different aircraft types. Flights using different aircraft types will have different costs and consequently different sensitivities to imposed sector-period unit rates.

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Input data (from DDR2/NEST)

- Chosen day: Friday 12 September 2014 (4^{th} busiest day in 2014, 33810 flights)

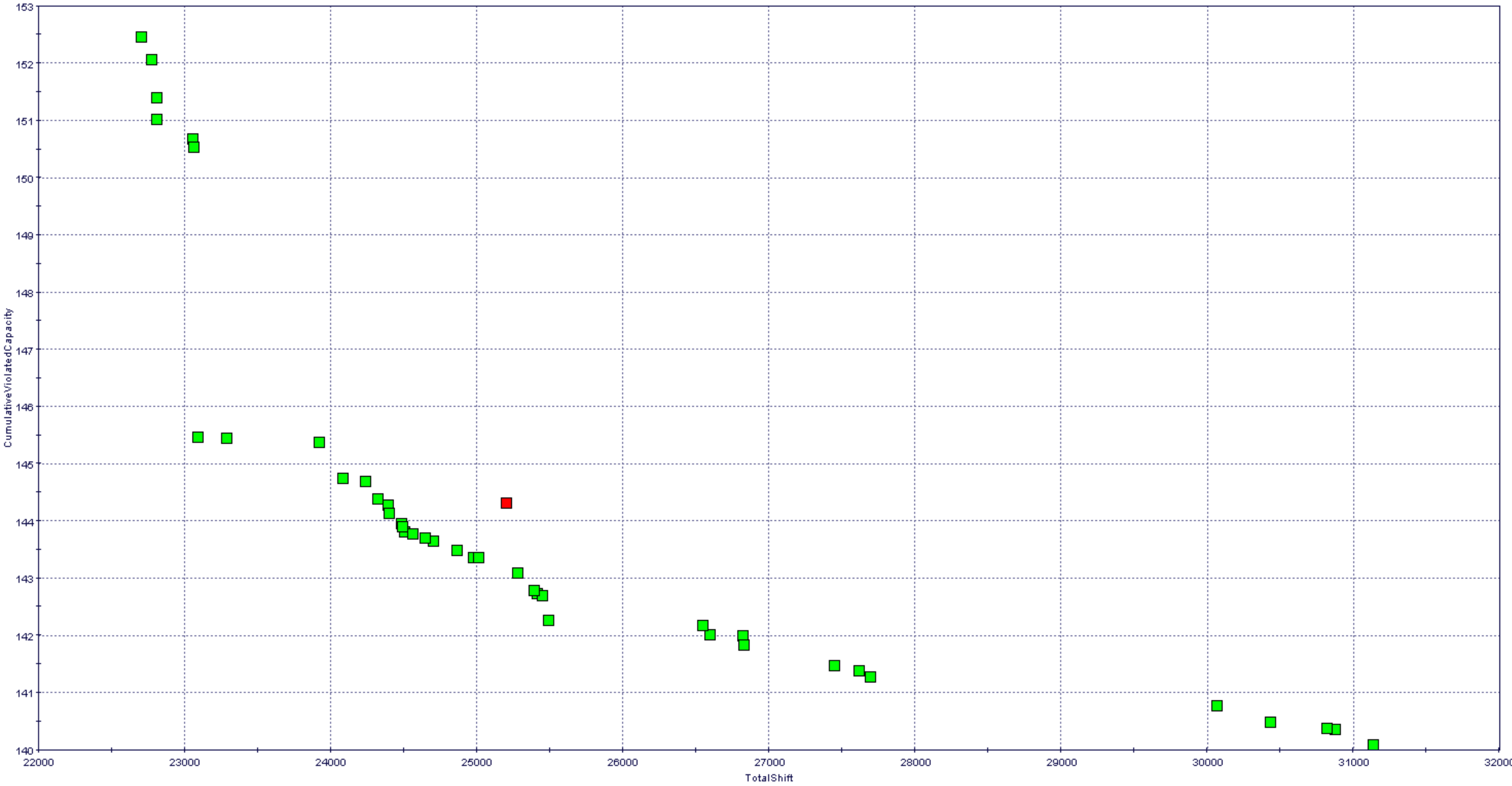
- Departure/arrival times (so6 m1 files – last filed flight plan)
  - Last filed flight plans (i.e. submitted a few hours before the departure) may have been subject to tactical revision, and – strictly speaking – are not strategic
  - However, these are the earliest flight plans available to us

- Set of flown routes between each O/D pair
  - Considering the two preceding weeks + Route clustering

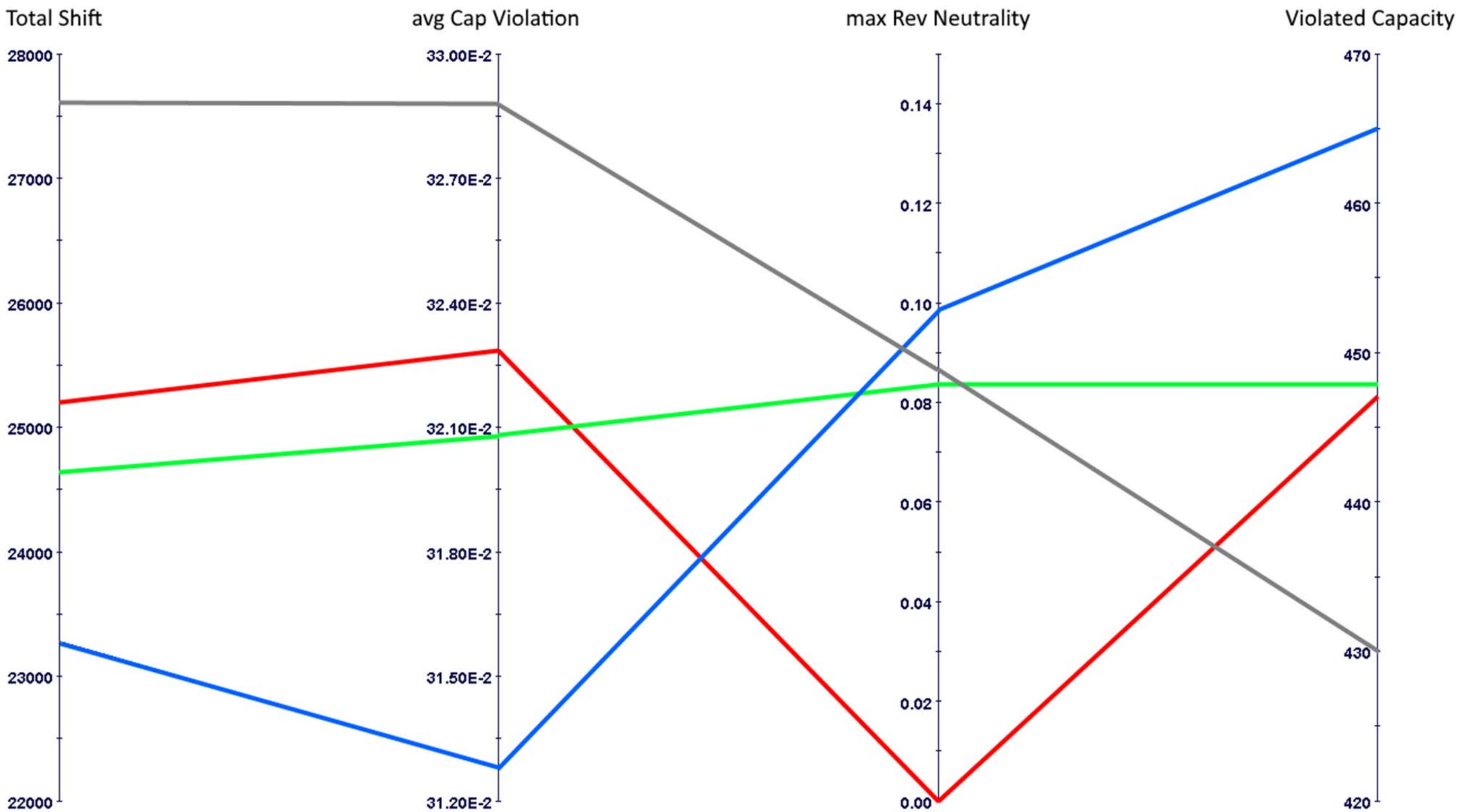
- Aircraft clustering (15 aircraft types)

Baseline scenario

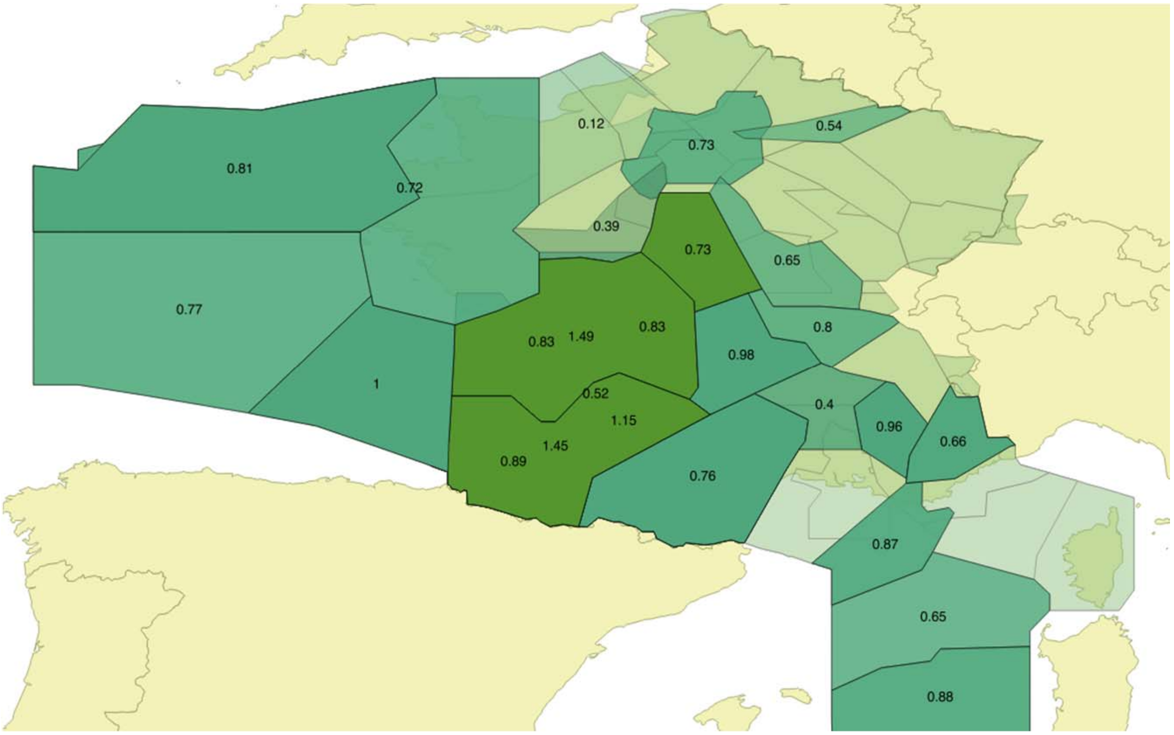
CPLP – Capacity violation vs. Shift



CPLP – Trade-offs (Parallel chart)



PLP by only one ANSP
France 06:00-10:59



Load on capacitated active sectors at 10:00 on 12 September 2014 (historical data)

	6:00		7:00		8:00		9:00		10:00	
	Lffp	CPLP	Lffp	CPLP	Lffp	CPLP	Lffp	CPLP	Lffp	CPLP
Avg. sector load	0.79	0.23	0.75	0.58	0.71	0.64	0.85	0.76	0.78	0.53
N. of sectors 0-30% load	2	25	2	2	1	2	3	2	3	9
30-70% load	15	11	19	29	21	24	9	12	11	21
70-100% load	11	0	11	6	12	11	20	19	20	7
>100% load	8	0	6	1	5	2	7	6	5	2
N. of capacity-constrained sectors	36		38		39		39		39	
N. of active sectors	90		95		100		99		100	

LF Unit Rate (Sep. 14) € 65,92

LF Peak rate € 71,12

LF Off-peak rate € 62,64

No rate modulation for all other countries

Decentralised PLP

Conclusions

- SATURN shows it is possible to “borrow” suitable pricing principles from other network industries and apply them to the European ATM system to manage capacity more efficiently

Open issues and future work

- Tune ANSPs' cost function (fixed + variable components?).
- Extend route choices
- Understand how critical are capacity violations
- Consider AO's requested departure and arrival times
- Evaluate robustness of the model
  - I.e., what happens in the tactical phase?