An Integrated Modelling Approach for Climate Impact Assessments in the Future Air Transportation System – Findings from the WeCare Project

Robin Ghosh*, Kai Wicke*, Katrin Kölker*, Ivan Terekhov*, Florian Linke*, Malte Niklaß*, Benjamin Lührs**, and Volker Grewe***

* German Aerospace Center (DLR), Air Transportation Systems

** Hamburg University of Technology (TUHH), Institute of Air Transportation Systems

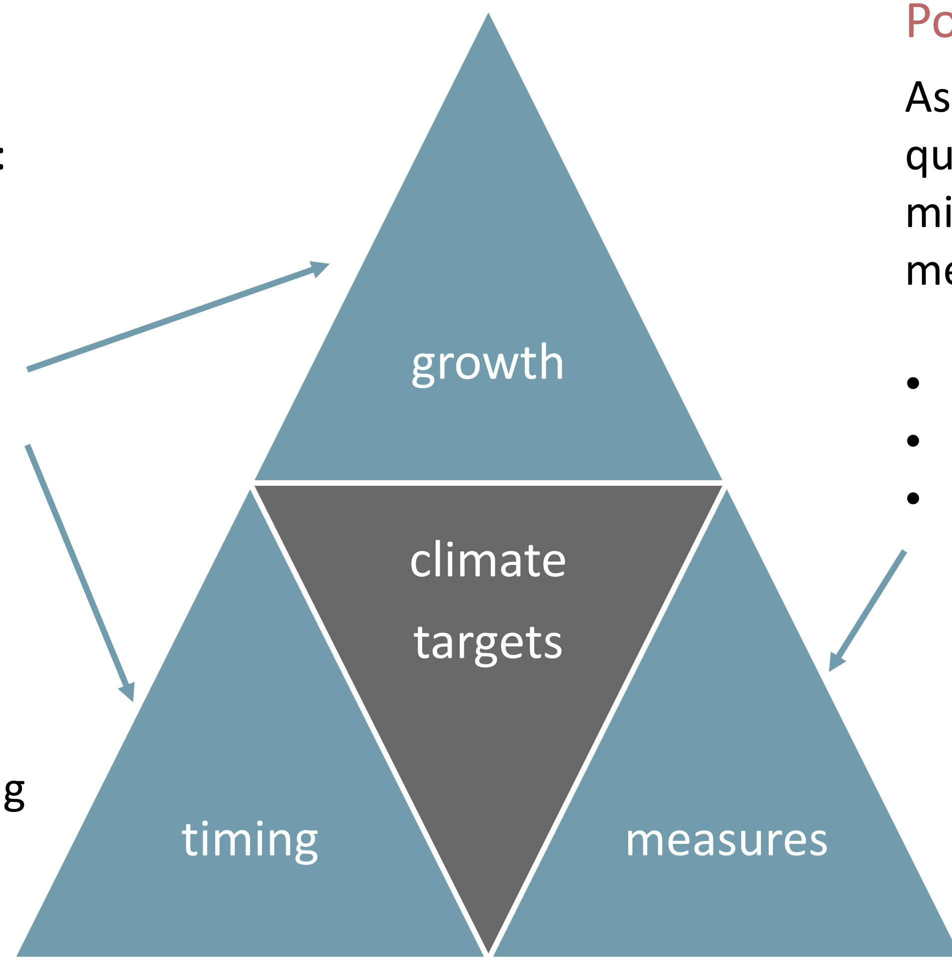
*** German Aerospace Center (DLR), Institute of Atmospheric Physics

Part 1 quantity structures and timing & Part 2 potentials of mitigation strategies

Future scenarios

Simulating quantity structures & timing:

- Modelling **growth on city pair level**
- evolution of the global ATS over time
- System‘s inertia with respect to decision making or policy planning



Potentials

Assessment and quantification of mitigation potentials of measures:

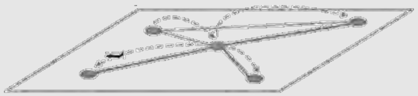
- **Operational**
- **Technological**
- **Policy**

Why are we designing the AIRCAST environment?

AIRCAST quantifies decision scenarios for aviation

Global passenger & air traffic forecasts on city pair level

Network and fleet forecasting combined

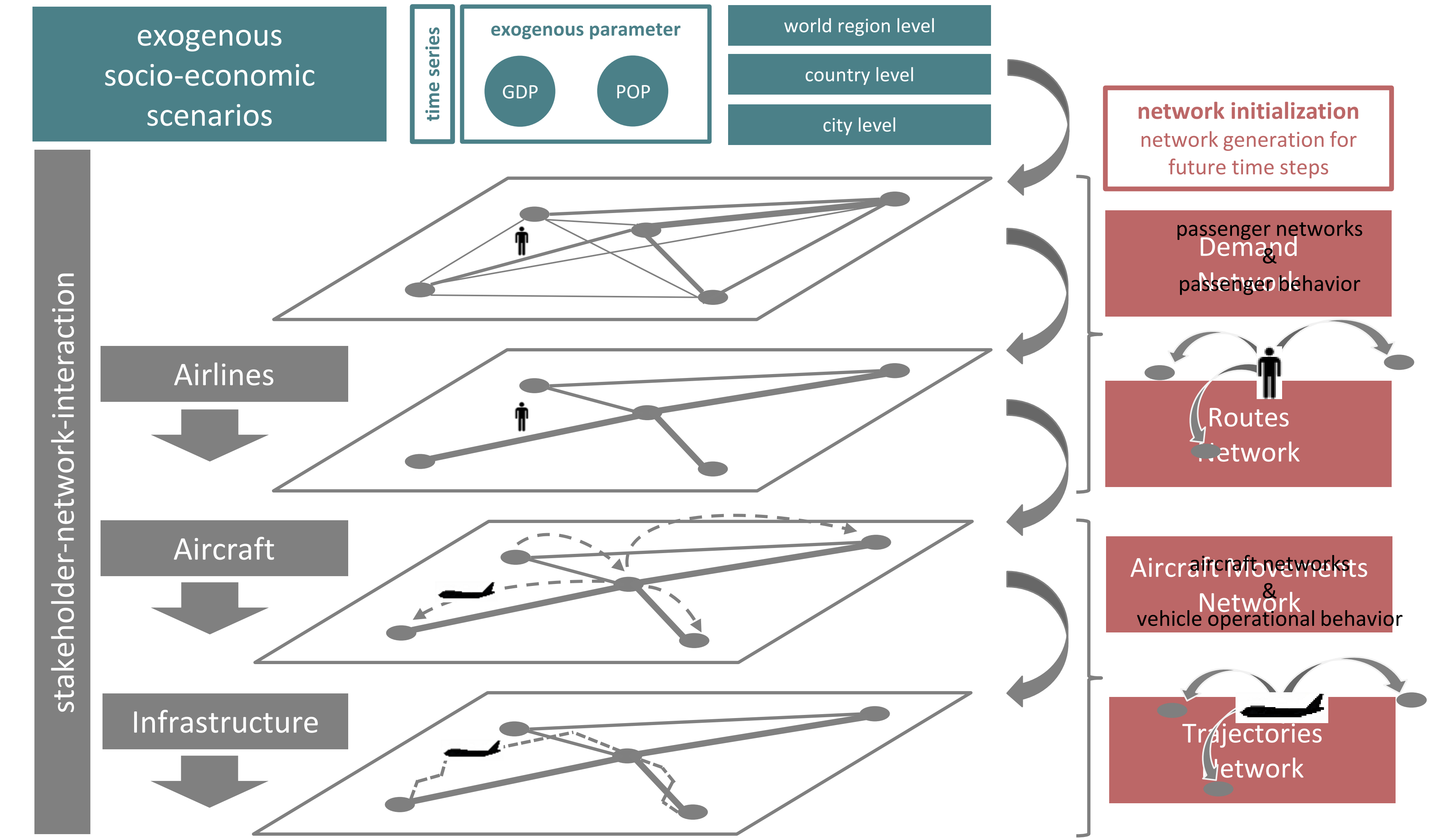


Assessing global aviation climate impacts

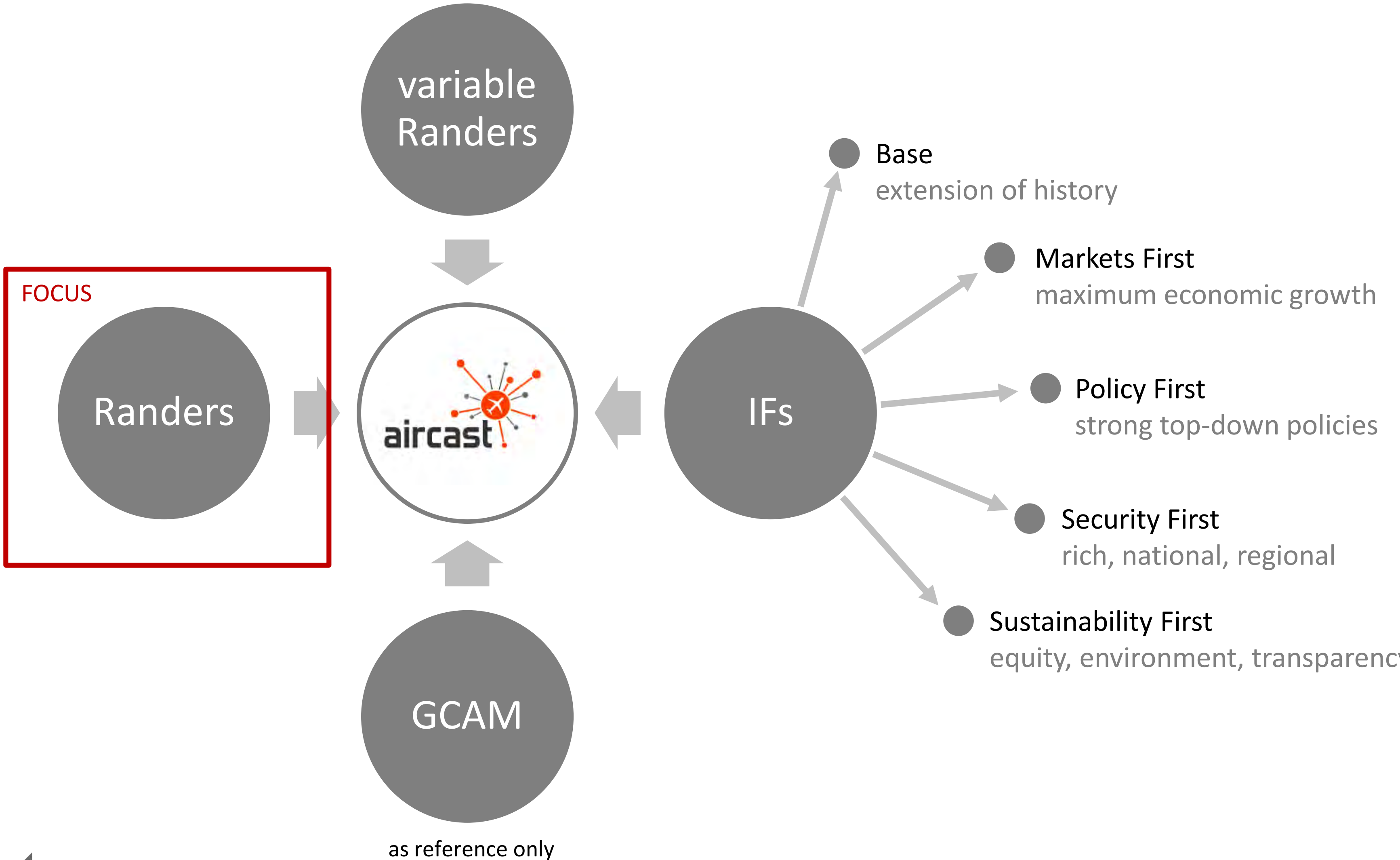
Strategy development: goals, growth & technology

DLR

4-Layer Philosophy



Overview of possible Input quantitative Scenarios



DLR

Randers Scenario – CITYCAST model

Network initialization: ATS *city pair* dimensions

exogenous socio-economic scenarios

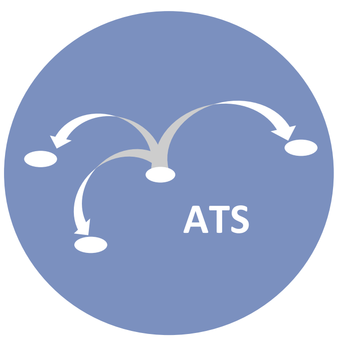
time series

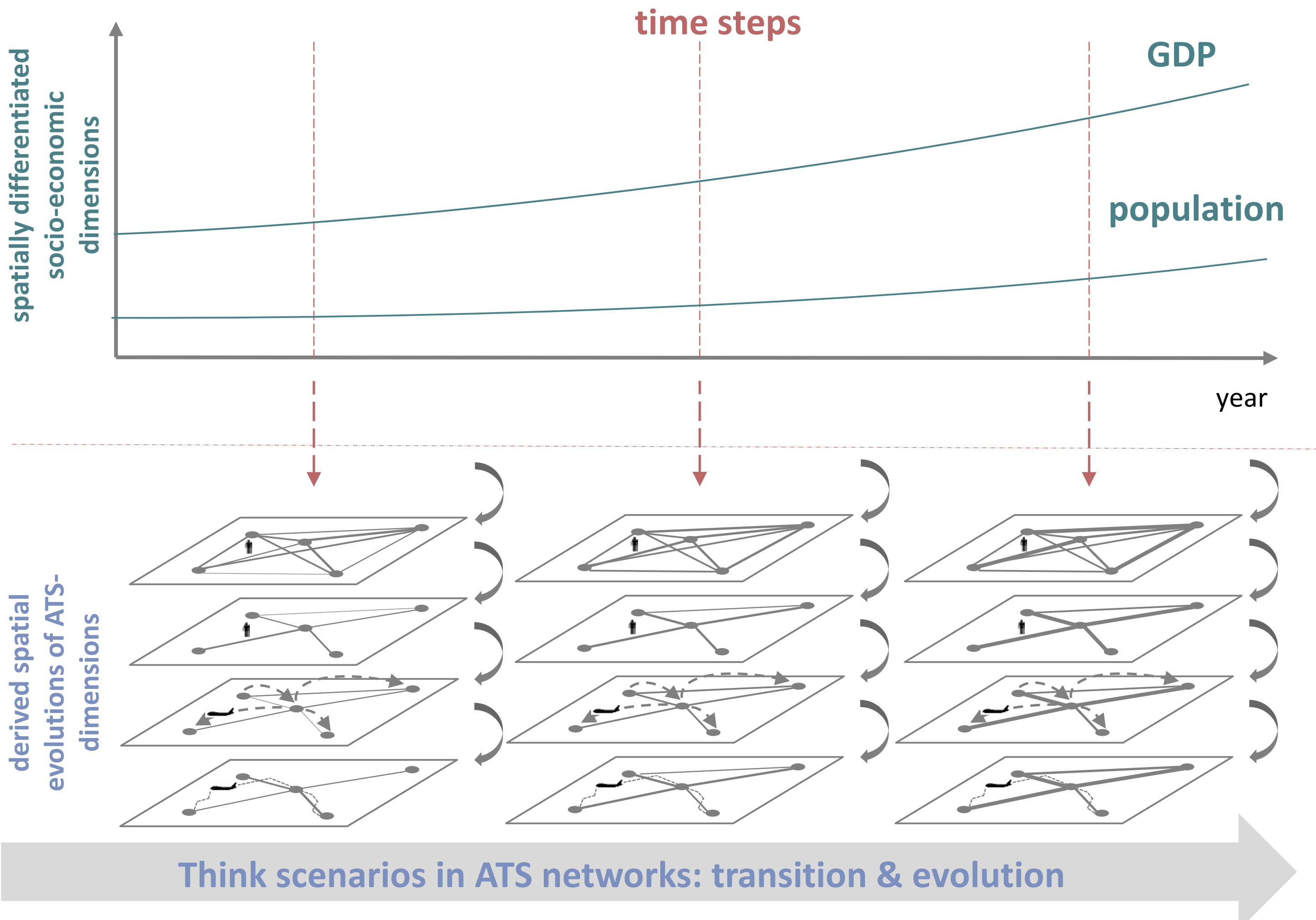
exogenous parameter

BIP

POP

network initialization
network generation for future time steps





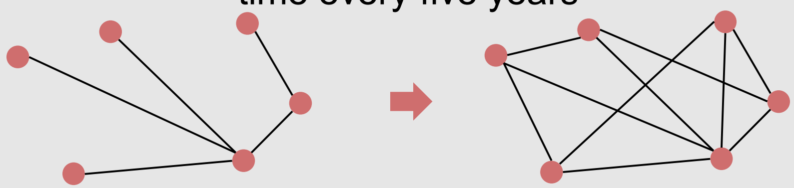
DLR

Air passenger demand forecasting – 2 Steps

exogenous socio-economic scenarios

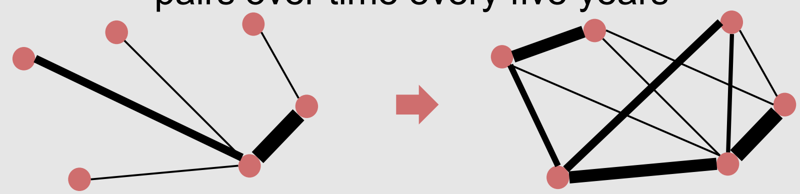
origin-destination demand network

TOPOLOGY-FORECAST
Evolution of the demand network topology over time every five years



first predicted time slice — time slice 2050

PASSENGER-FORECAST
Evolution of the number of passengers on city pairs over time every five years



first predicted time slice — time slice 2050

routes network

aircraft movements network

trajectories network

cost

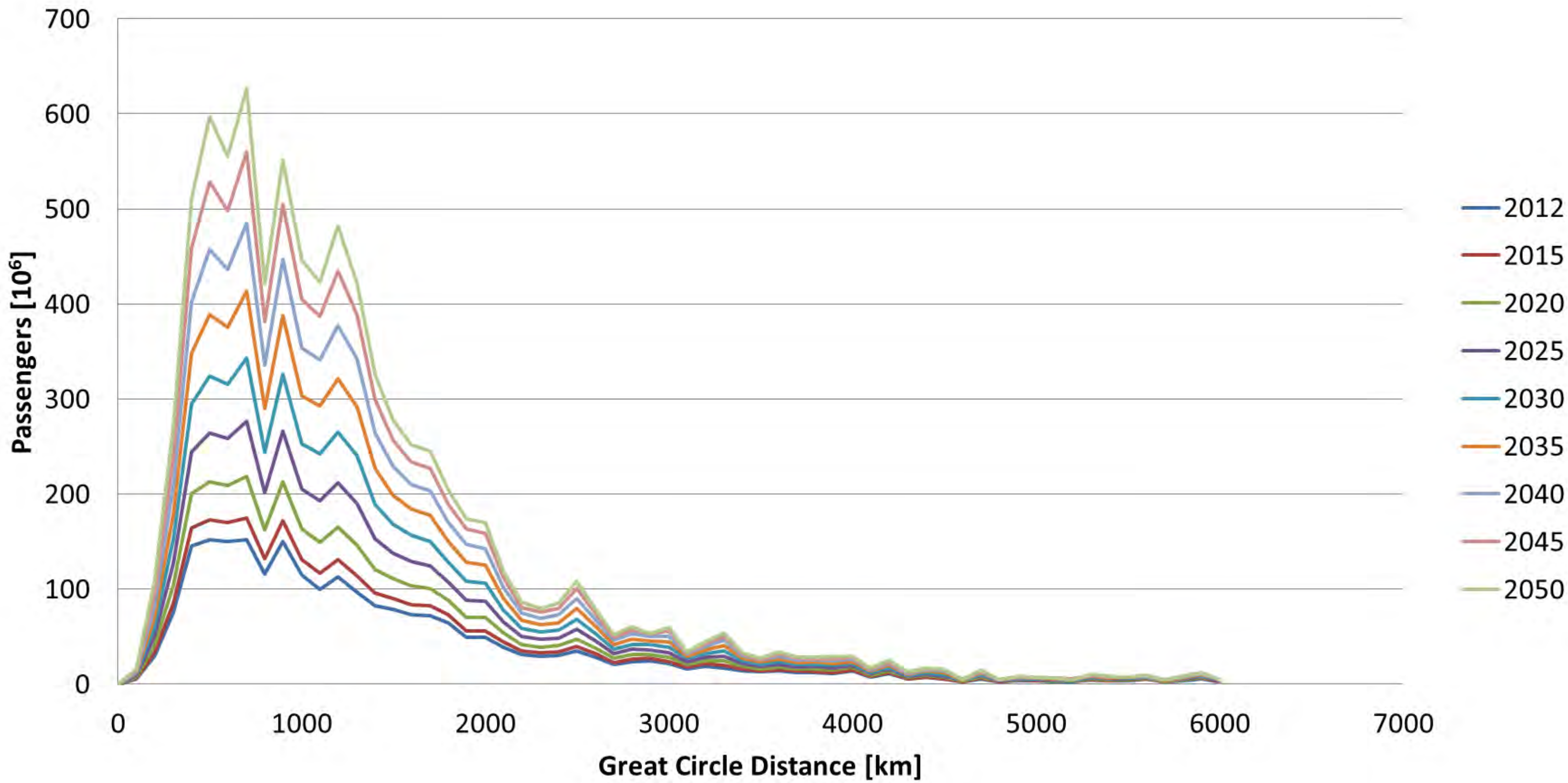
- new technologies
- direct and indirect operating cost

quality of travel

- frequency
- travel time
- number of transfers

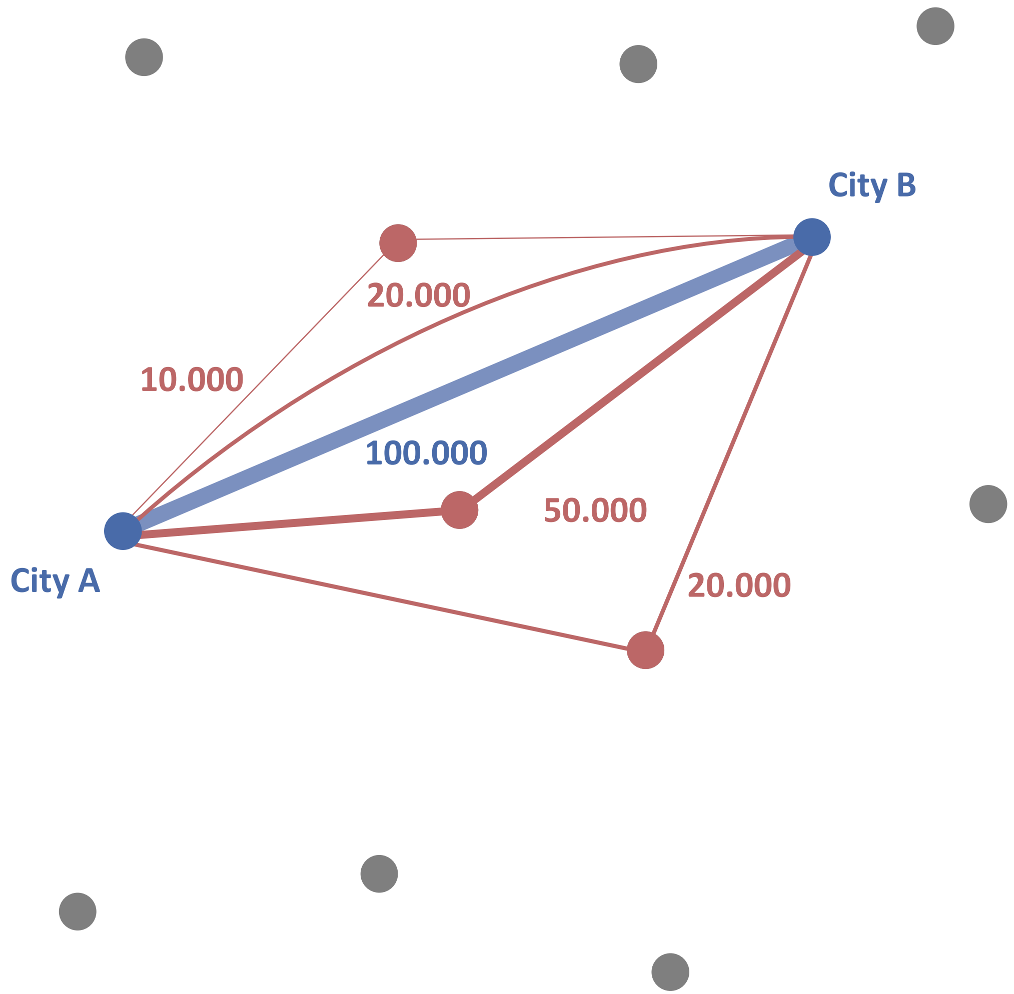
Air passenger demand under Randers scenario

Simulation results: Demand Network Layer



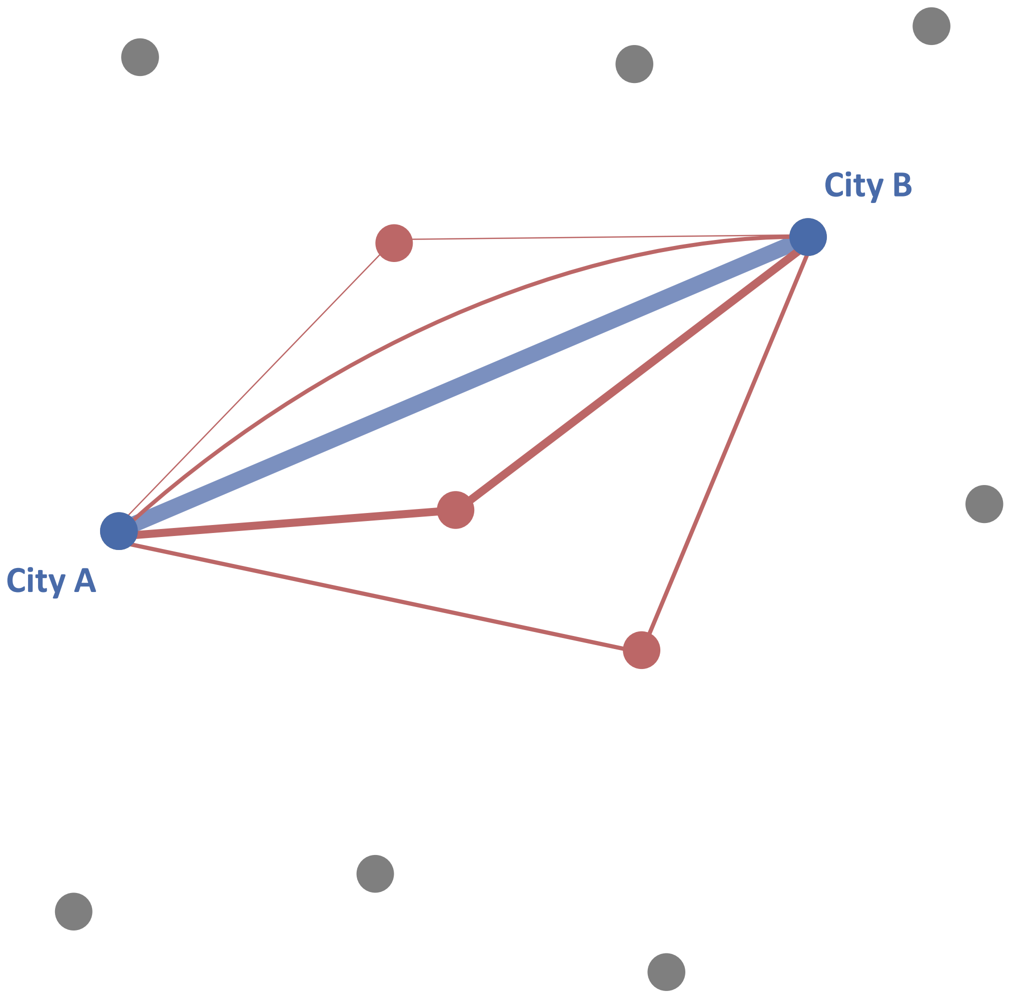
DLR

Modelling of passenger routes



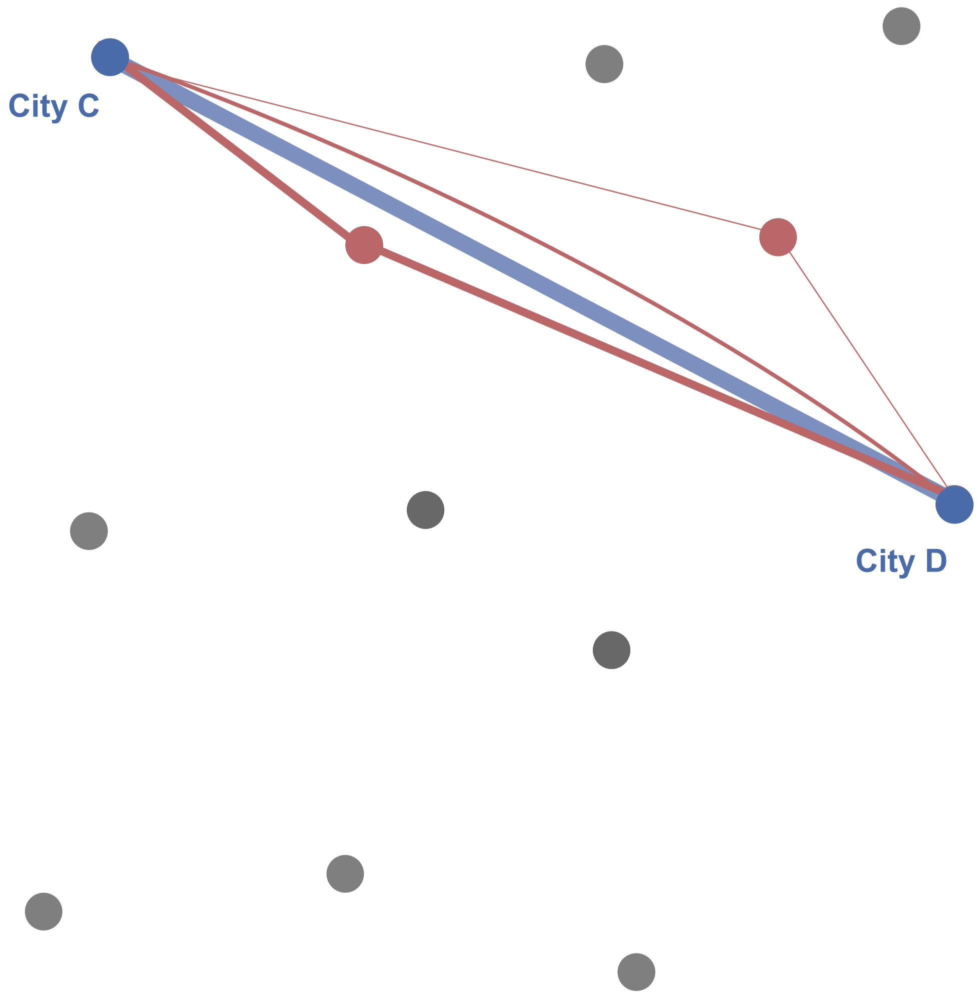
- Which routes are possible/reasonable?
  - list of possible transfer airports (ca. 500 worldwide)
  - minimum segment distance
  - maximum number of transfers
  - maximum detour factor
- What are the probabilities for the choice of a certain route?

Modelling of passenger routes



- Which routes are possible/reasonable?
  - list of possible transfer airports (ca. 500 worldwide)
  - minimum segment distance
  - maximum number of transfers
  - maximum detour factor
- What are the probabilities for the choice of a certain route?
- For all demand city pairs worldwide

Modelling of passenger routes

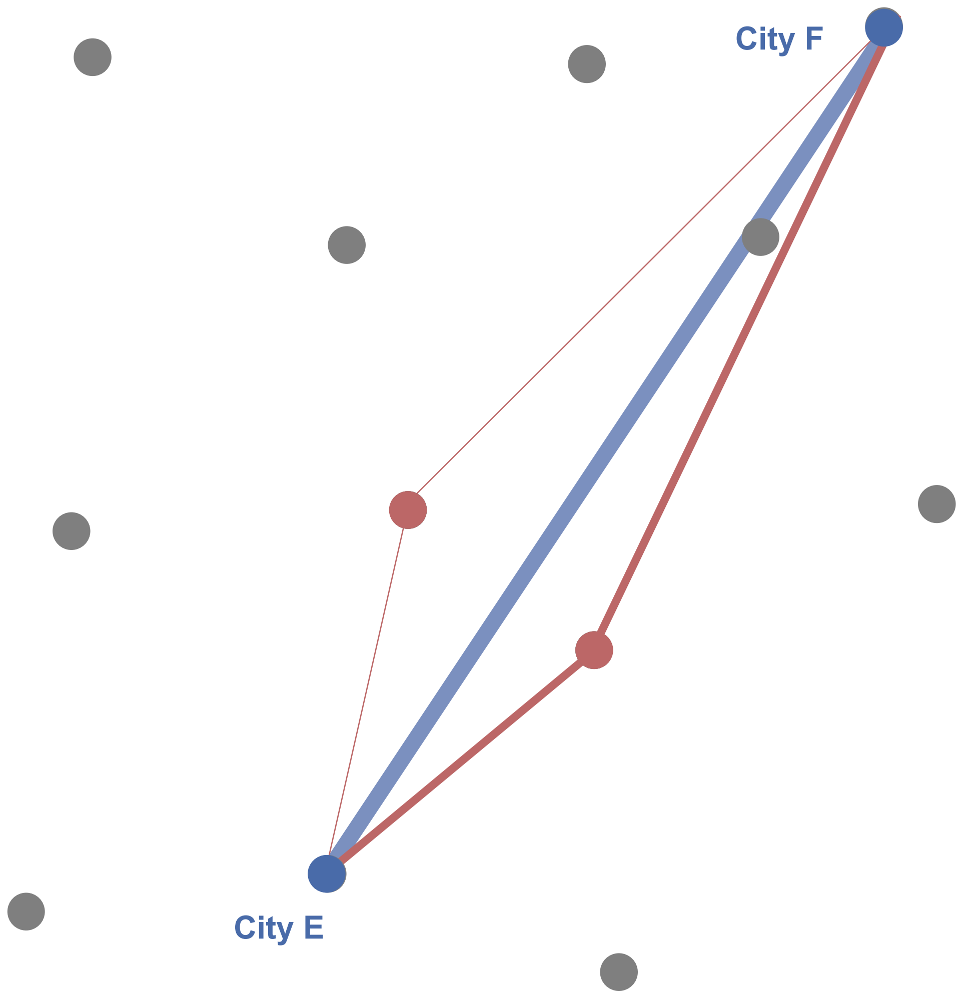


- Which routes are possible/reasonable?
    - list of possible transfer airports (ca. 500 worldwide)
    - minimum segment distance
    - maximum number of transfers
    - maximum detour factor

- What are the probabilities for the choice of a certain route?

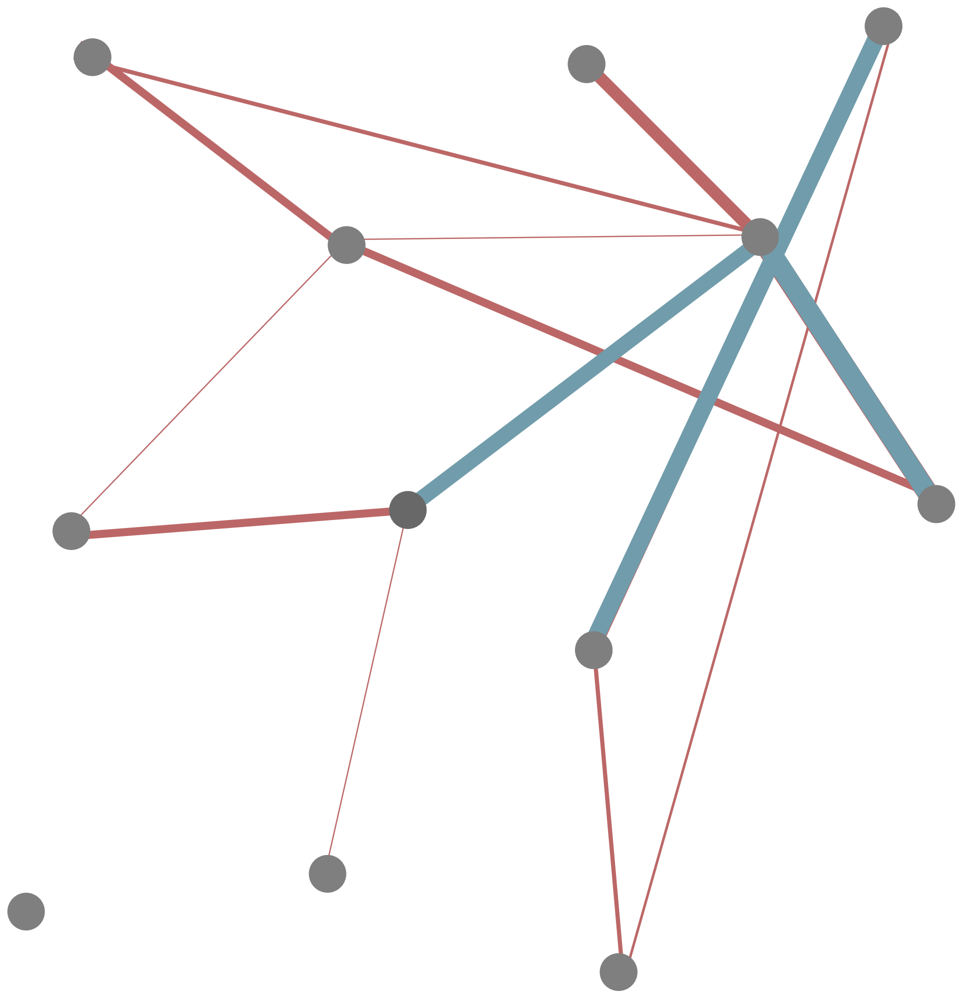
- For all demand city pairs worldwide

Modelling of passenger routes



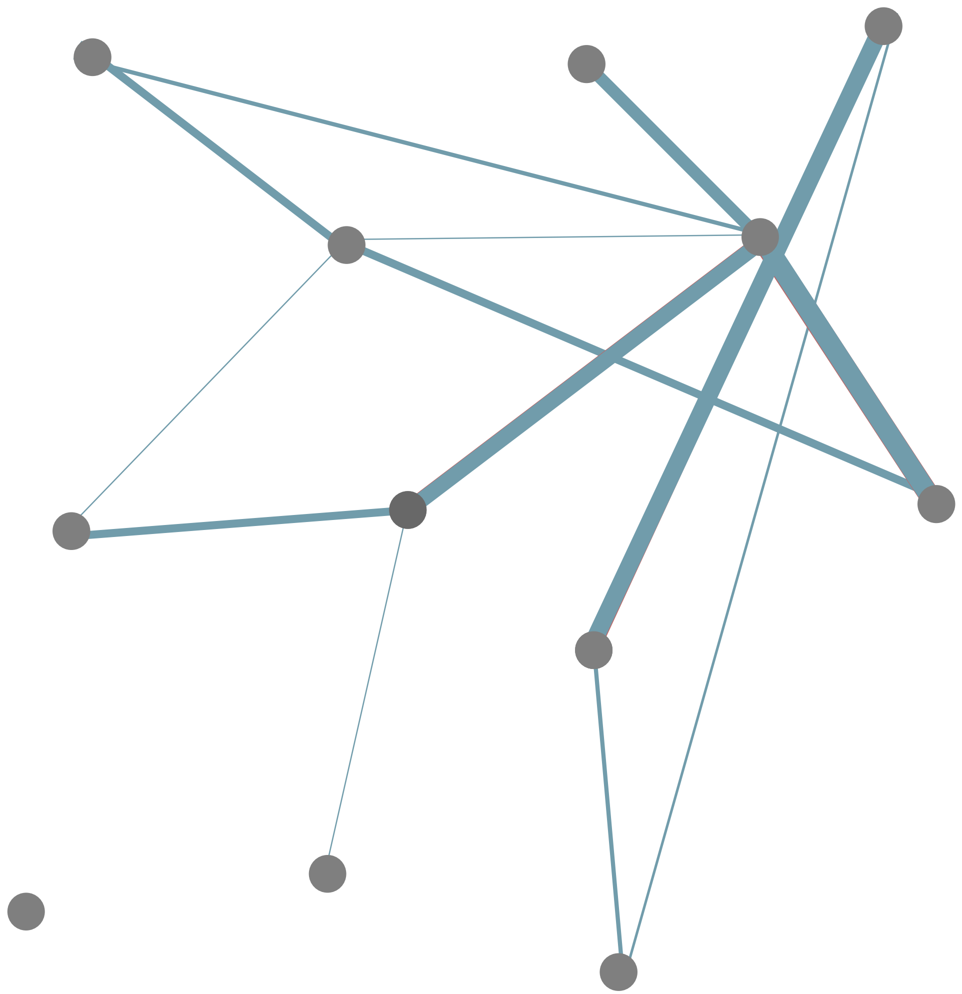
- Which routes are possible/reasonable?
  - list of possible transfer airports (ca. 500 worldwide)
  - minimum segment distance
  - maximum number of transfers
  - maximum detour factor
- What are the probabilities for the choice of a certain route?
- For all demand city pairs worldwide

Passengers on segments



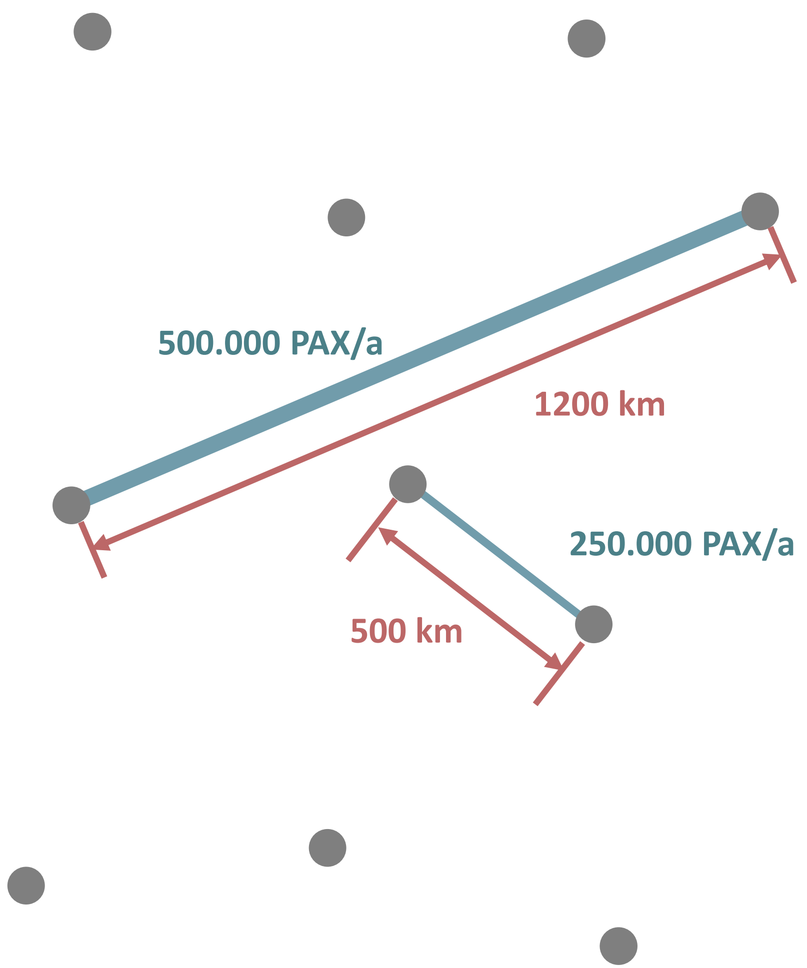
Goal:
Deduce passenger volumes on segments worldwide

Deducing an aircraft movements network

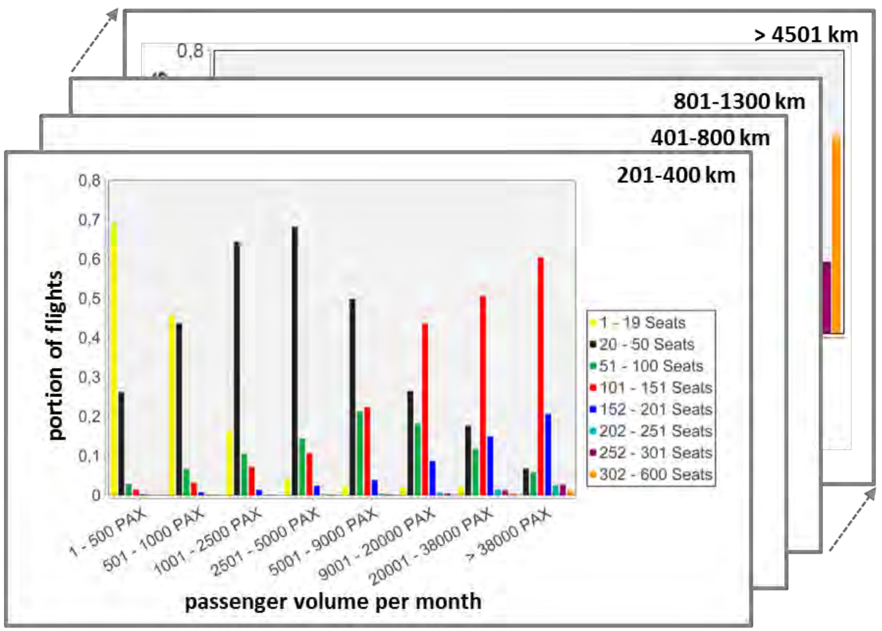


- …, because the portion of deployed aircraft sizes are a function of:
  - segment distance
  - passenger volume on segment
- aircraft sizes are abstracted in seat categories

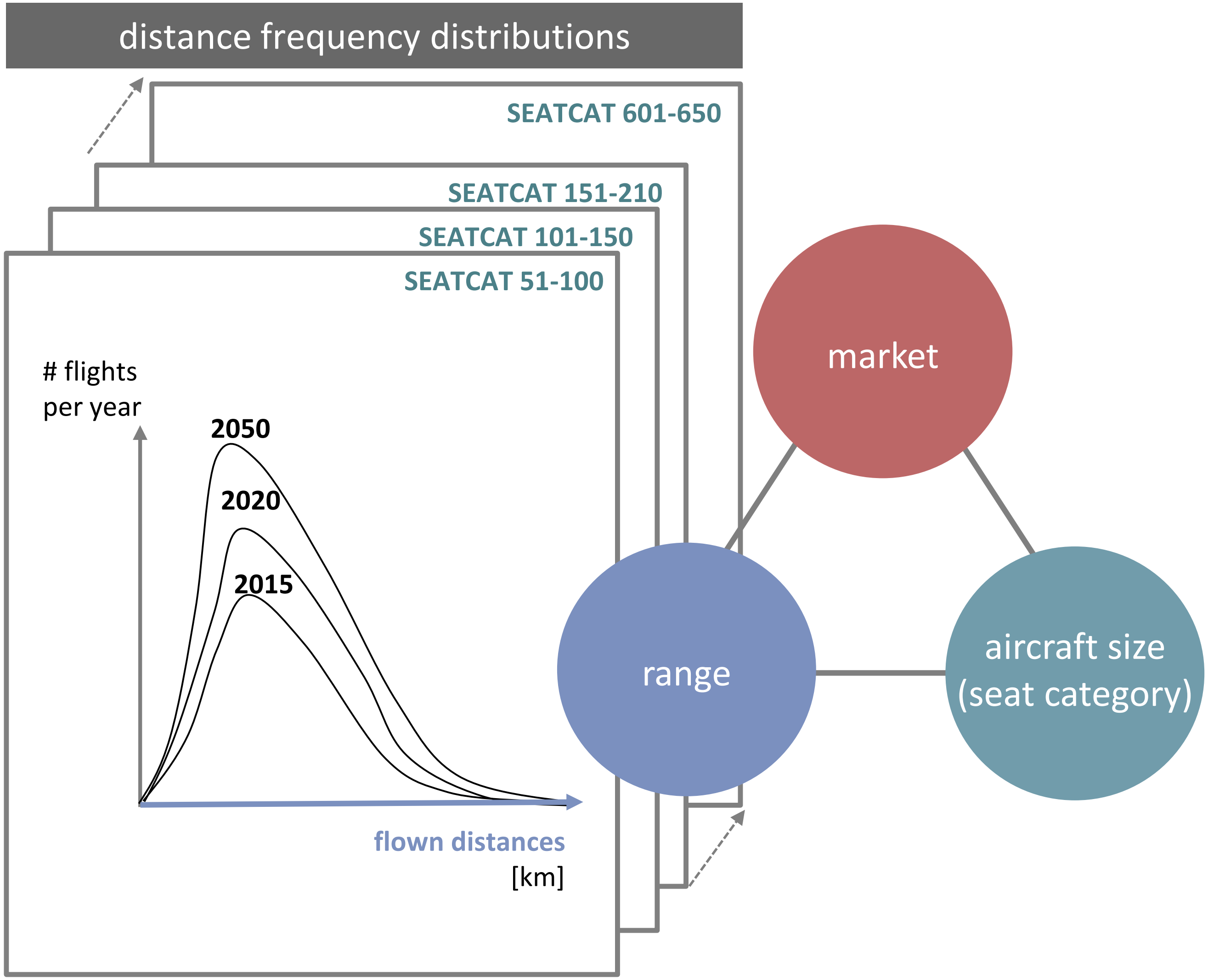
Aircraft movements on segments by seat categories



How many flights are performed by which seat categories on which segments?



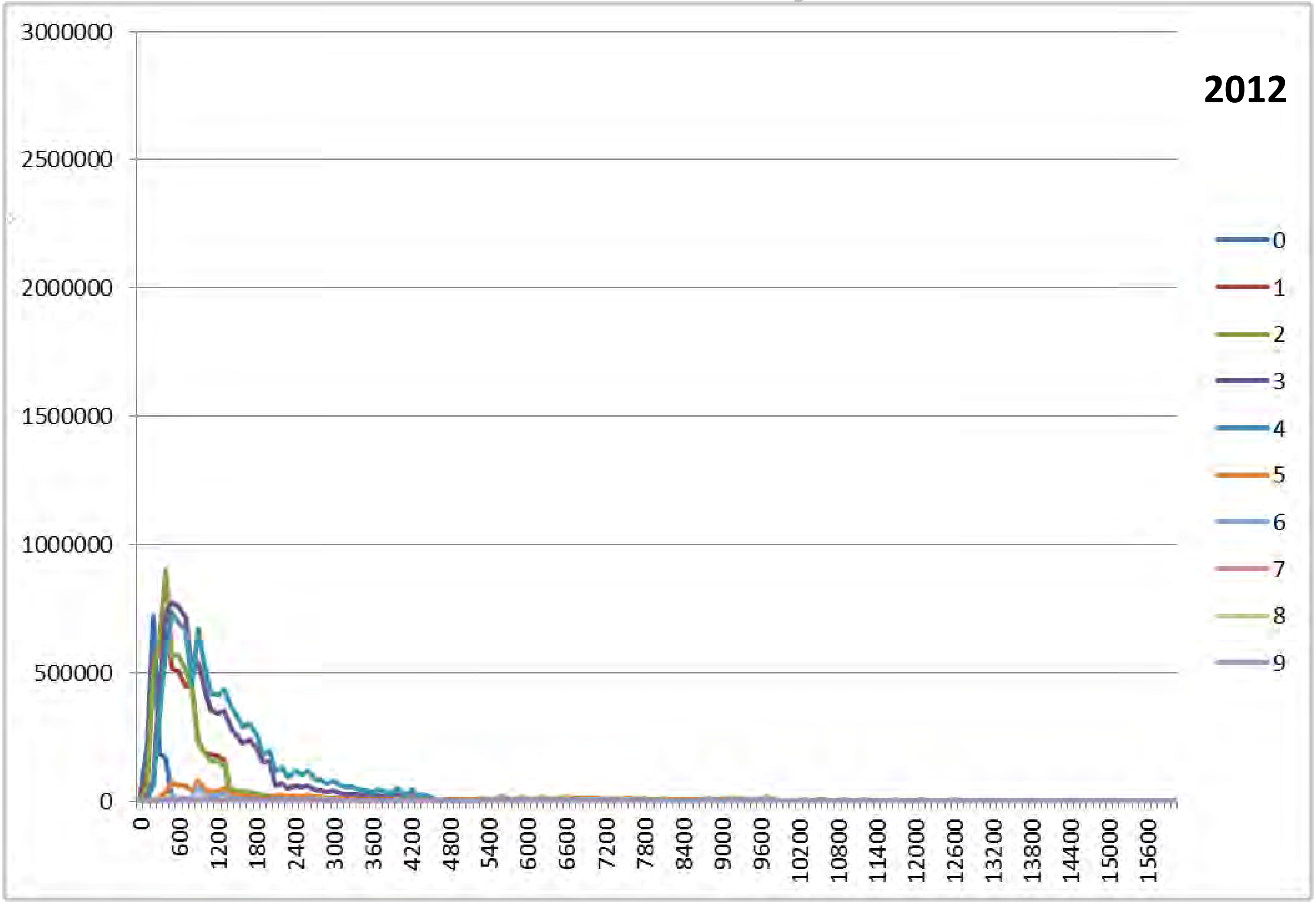
Market-size-range relation



seat categories	
9	601-650
8	501-600
7	401-500
6	301-400
5	211-300
4	151-210
3	101-150
2	51-100
1	20-50
0	<20

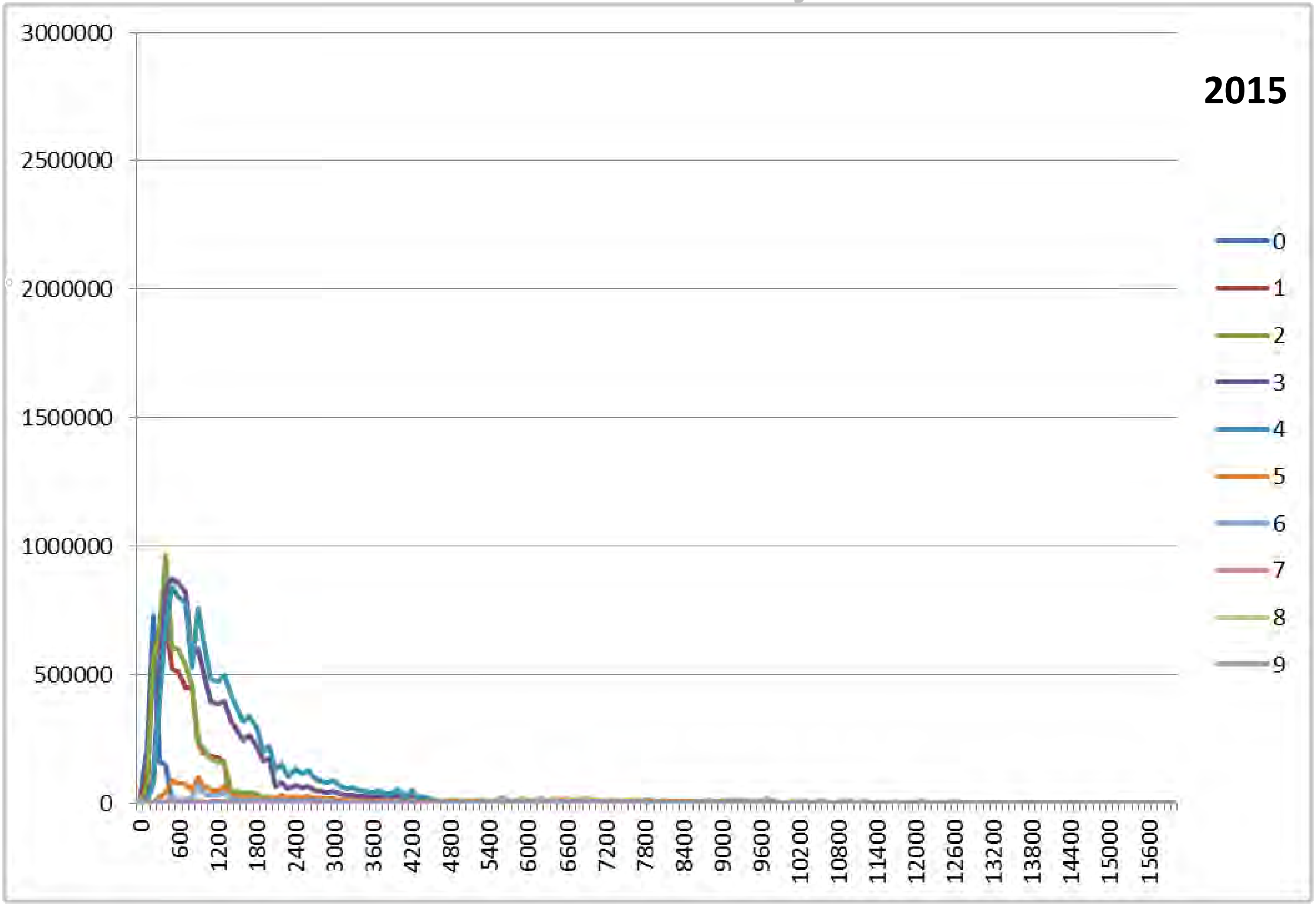
Distance-frequency-distributions (Randers scenario)

Simulation results: Aircraft Movements Network Layer



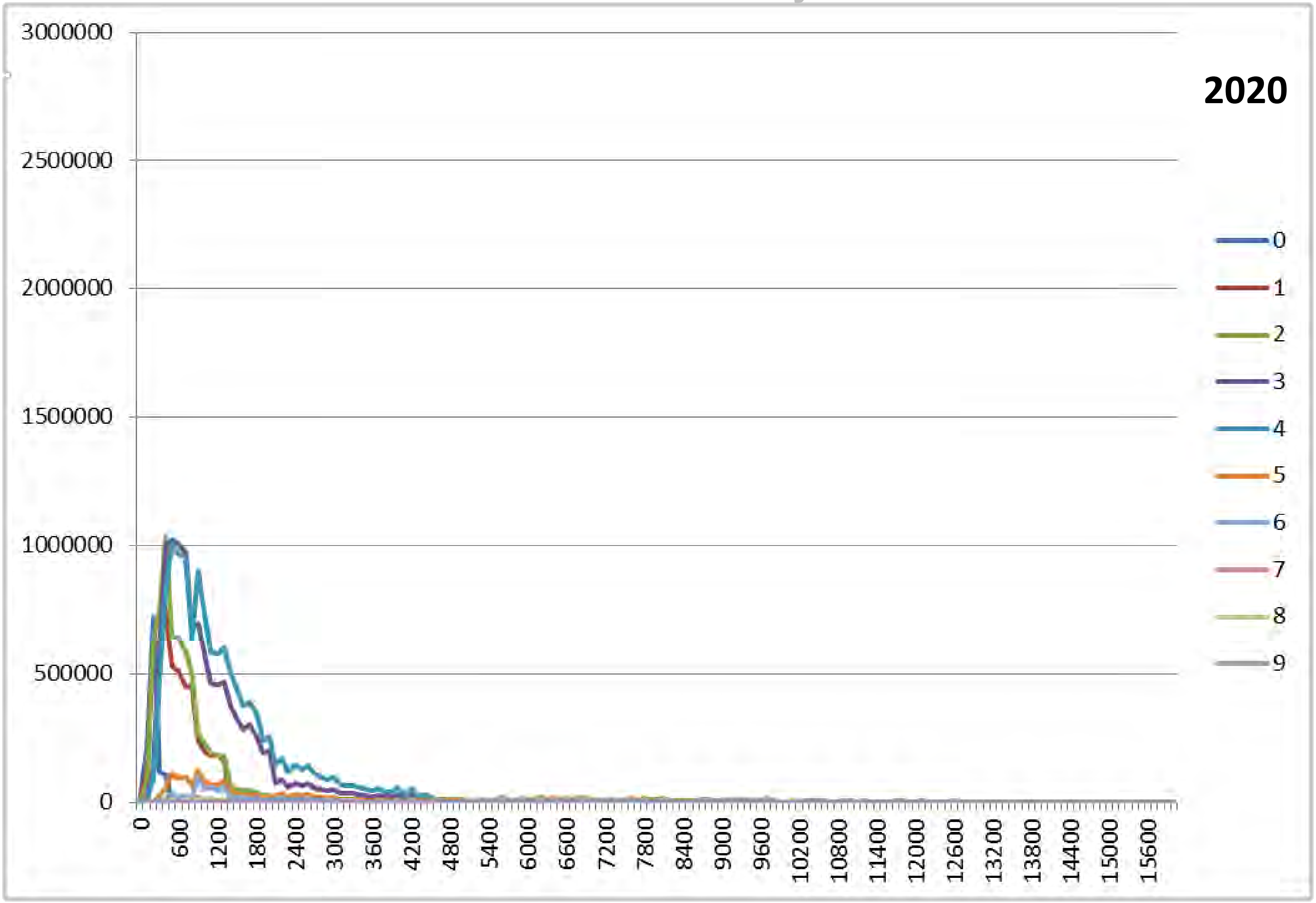
Distance-frequency-distributions (Randers scenario)

Simulation results: Aircraft Movements Network Layer



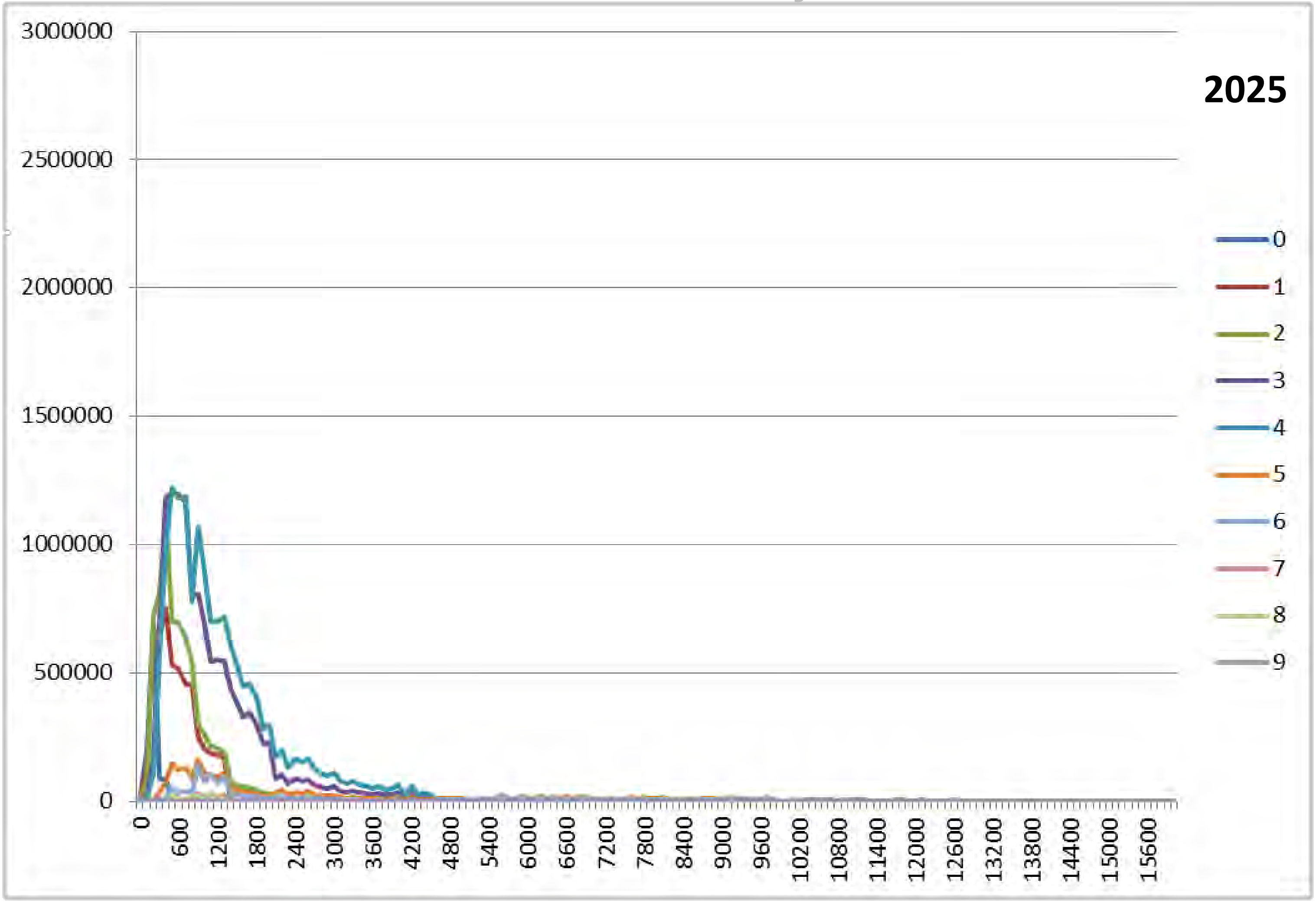
Distance-frequency-distributions (Randers scenario)

Simulation results: Aircraft Movements Network Layer



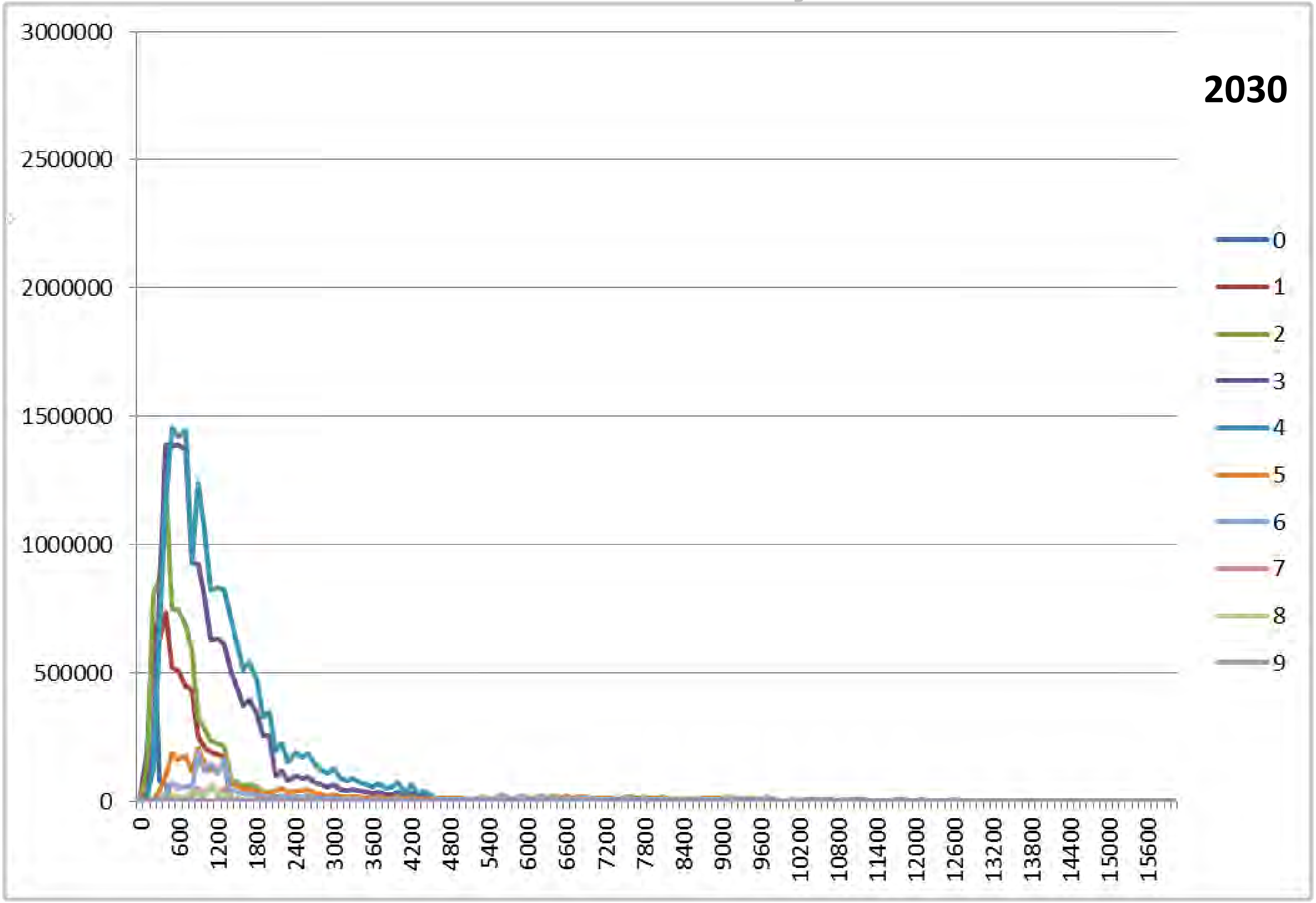
Distance-frequency-distributions (Randers scenario)

Simulation results: Aircraft Movements Network Layer



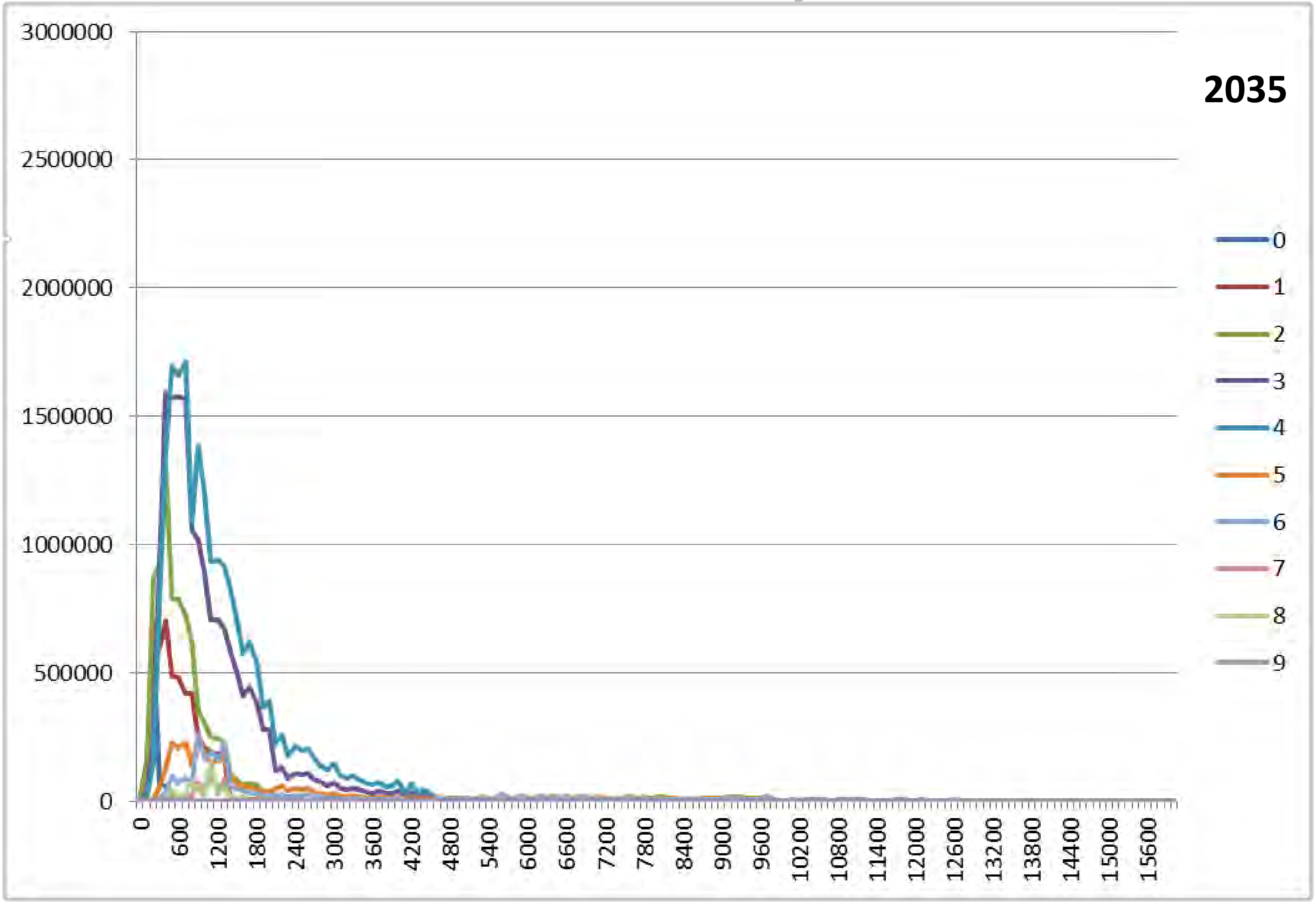
Distance-frequency-distributions (Randers scenario)

Simulation results: Aircraft Movements Network Layer



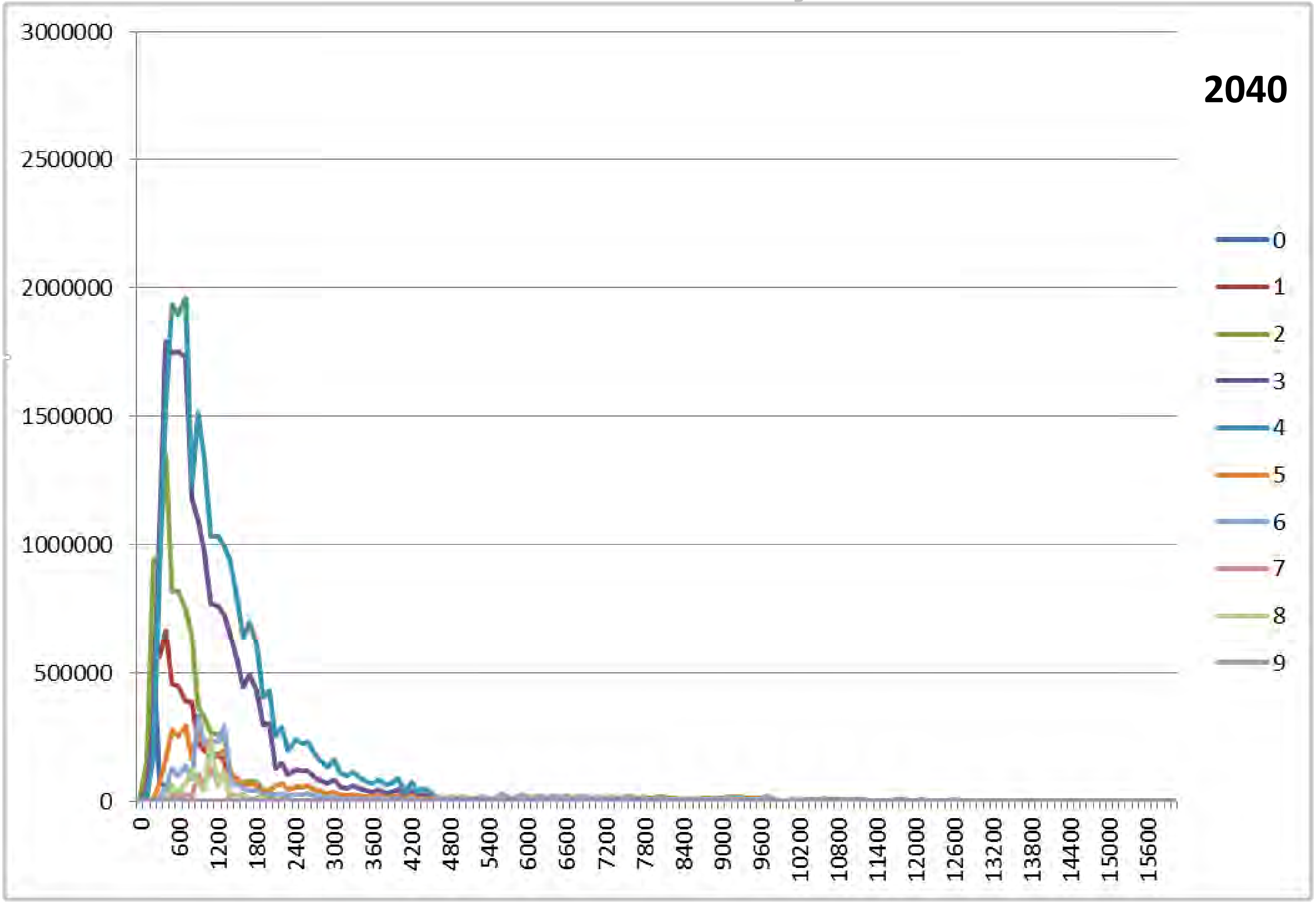
Distance-frequency-distributions (Randers scenario)

Simulation results: Aircraft Movements Network Layer



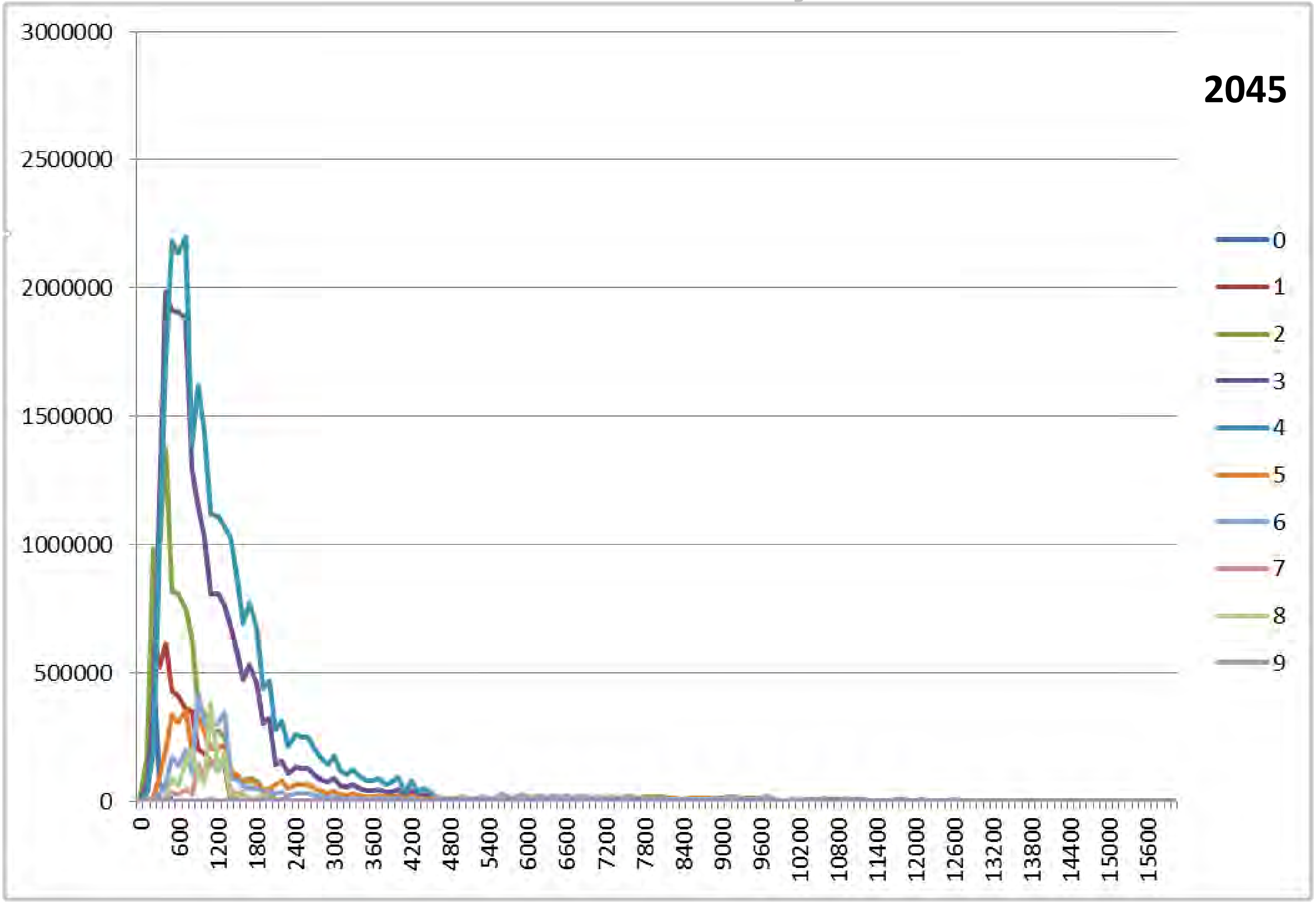
Distance-frequency-distributions (Randers scenario)

Simulation results: Aircraft Movements Network Layer



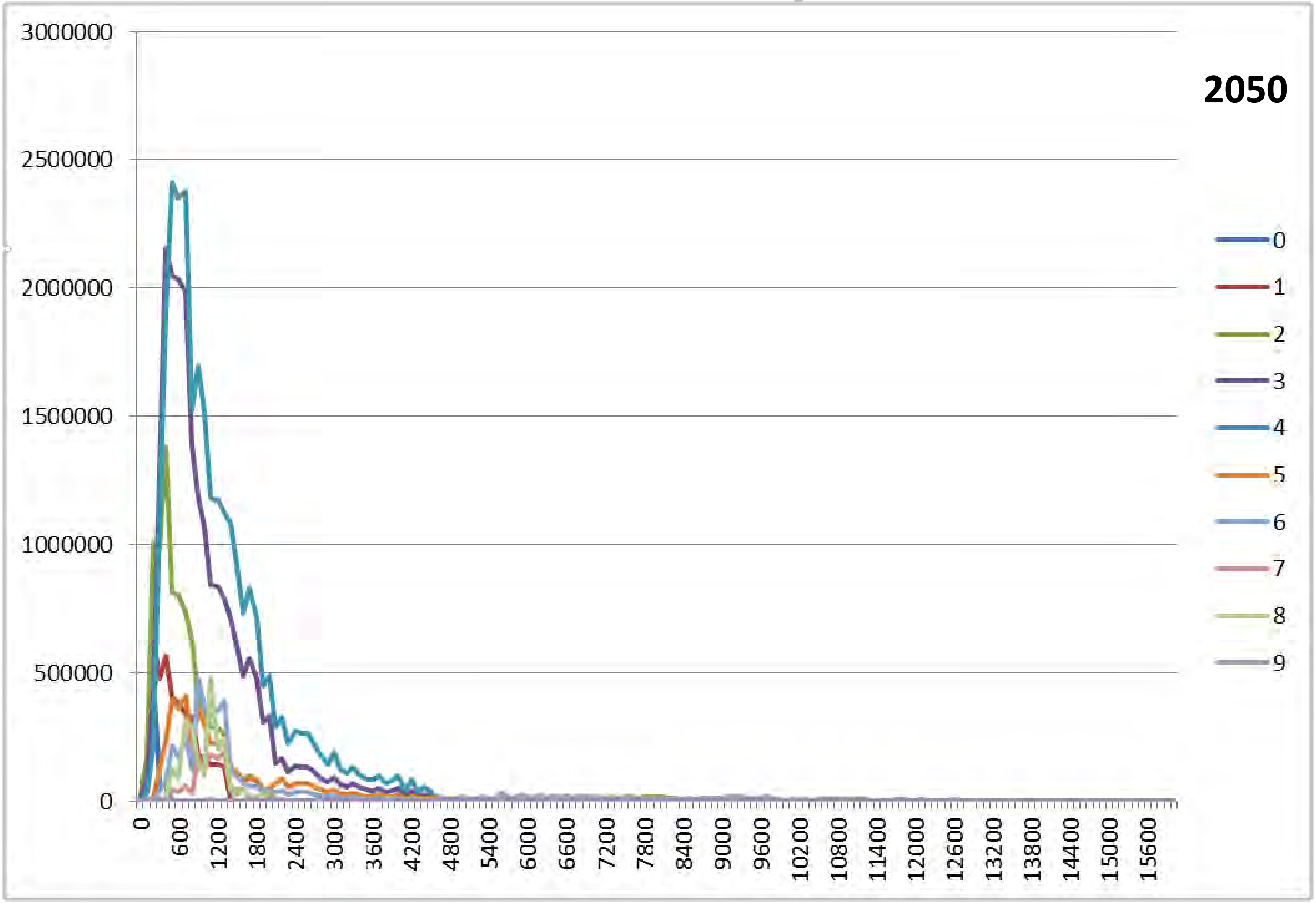
Distance-frequency-distributions (Randers scenario)

Simulation results: Aircraft Movements Network Layer



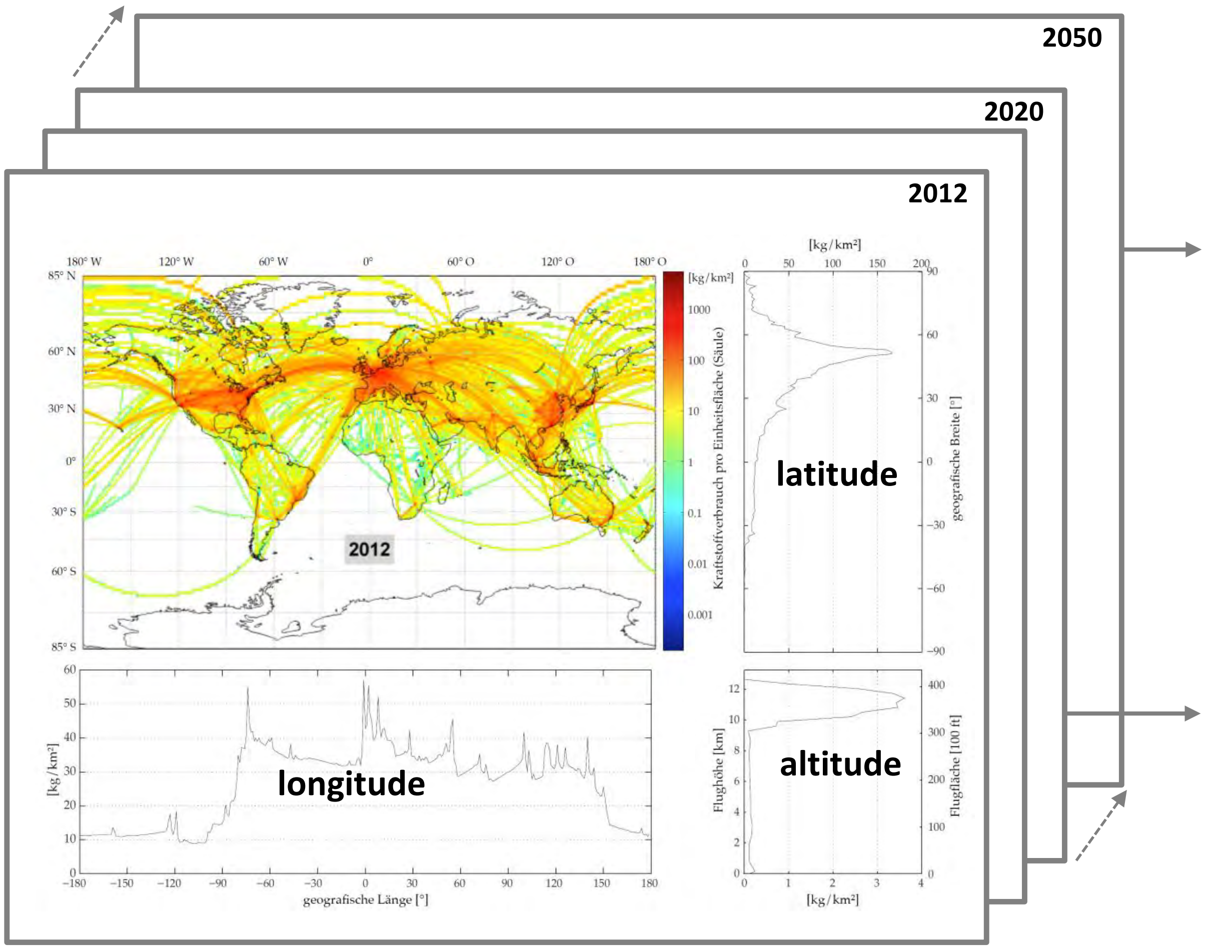
Distance-frequency-distributions (Randers scenario)

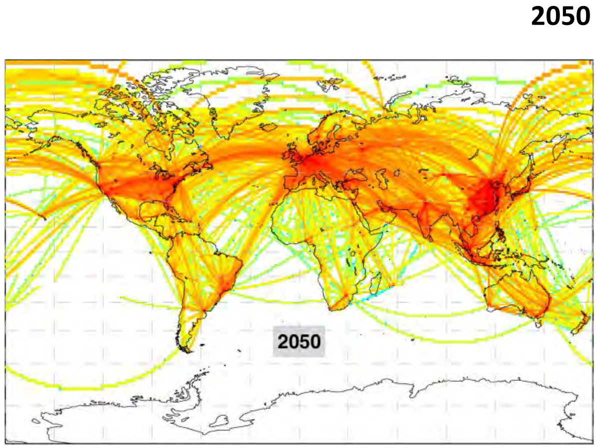
Simulation results: Aircraft Movements Network Layer

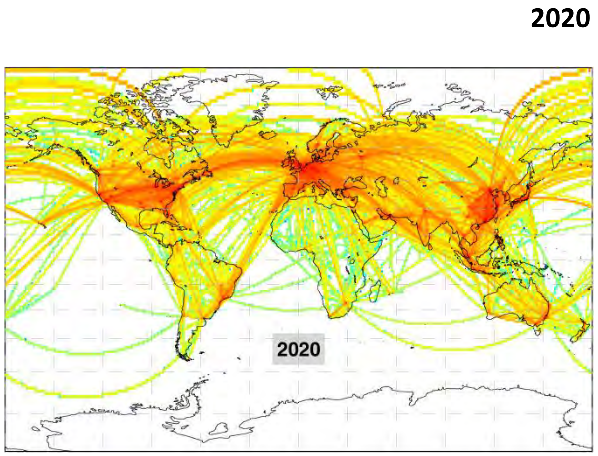


WeCare Part 1: emission inventories (Randers scenario)

Simulation results: Trajectories Network Layer (DLR Module GRIDLAB)





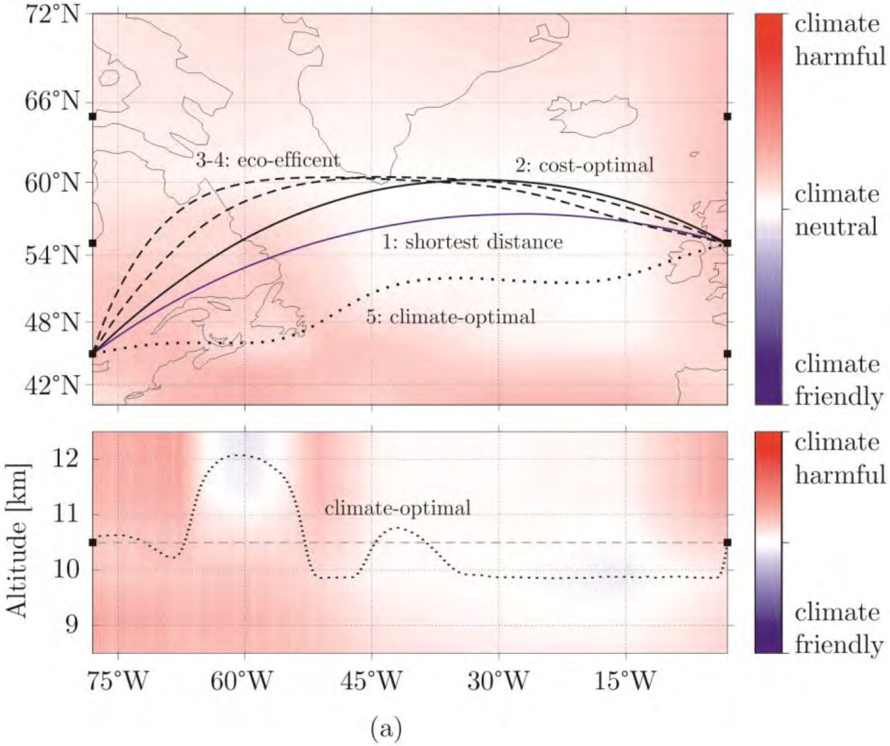


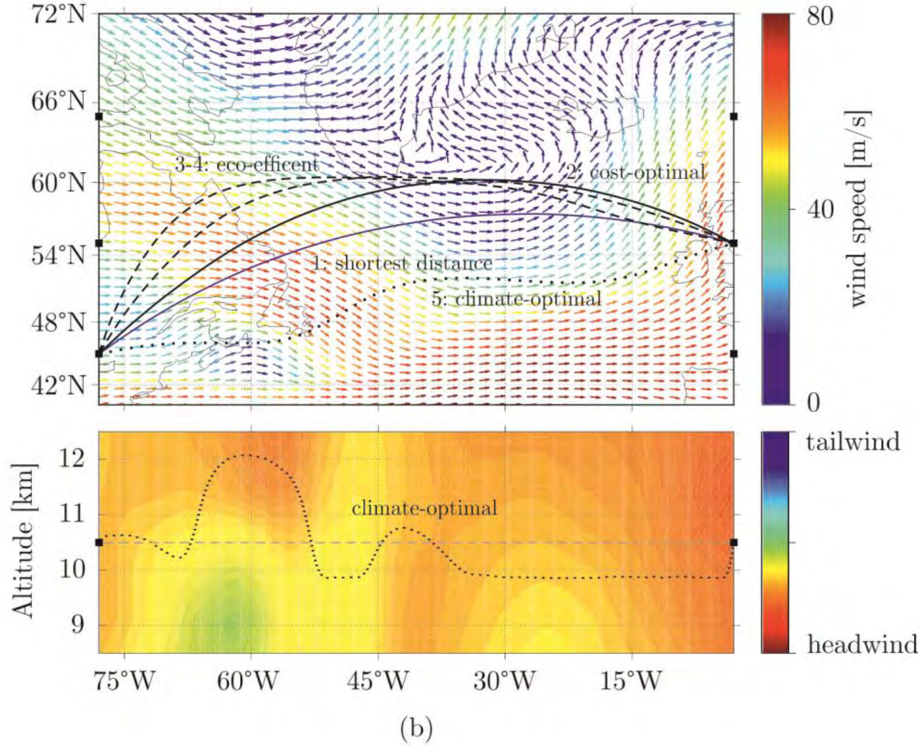
Linke 2016

DLR

WeCare Part 2: assessment of eco-efficient flight trajectories

Simulation results: Quantification of mitigation potentials (DLR Module TOM)





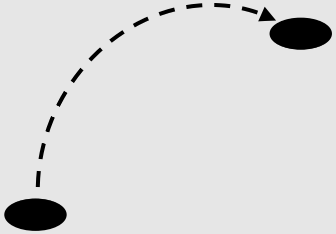
Lührs et al. 2016

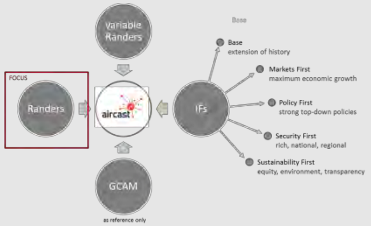
Outlook

Create aircraft movements network with **aircraft type and aircraft generation** information (assumed BAU-scenario of new aircraft)

Trajectory network calculation for Randers-Scenario (interface has been already defined)

- to prepare a prototype input for further models
- to provide an ATS **city pair „energy forecast“** including the capability of modelling the introduction of hybrid and alternative energy concepts





Run whole chain on IF-scenarios: **Create „scenario libraries“**

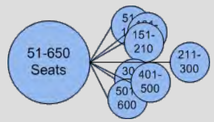
& Develop methods for collaborative working and workshops

Outlook: Aircraft movements network with aircraft generations

Fleet renewal model FFWD (Fast Forward)

1 Status quo

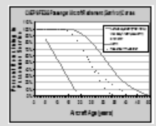
- Current fleet
  - Civil fleet
  - Sub-fleets



ASCEND fleet data

2 Aircraft categories

- Shares by seat category
- FESG retirement curves



ICAO FESG forecast

3 Growth scenario

- RPK growth: global and by seat categories
- Shift of market shares by seat categories
- Seat load factor sceanrio by seat categories

AIRCAST aircraft movements network

4 Fleet Forecast

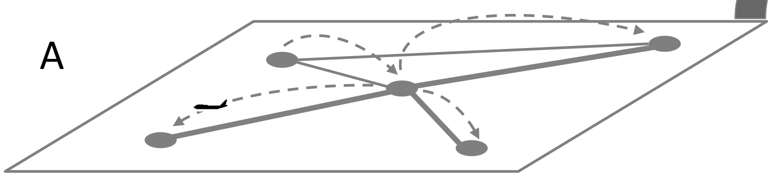
- Fleet in service
- Retirements
- Deliveries

5 New aircraft

- Technology timeline
- Introduction pattern over all seat categories
- Generic aircraft

AIRCAST aircraft movements network

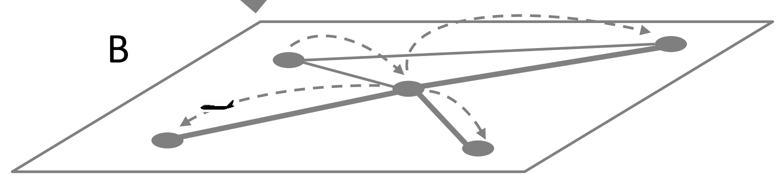
A



aircraft movements network

number of flights by seat category on segments

B



aircraft movements network with aircraft generation information

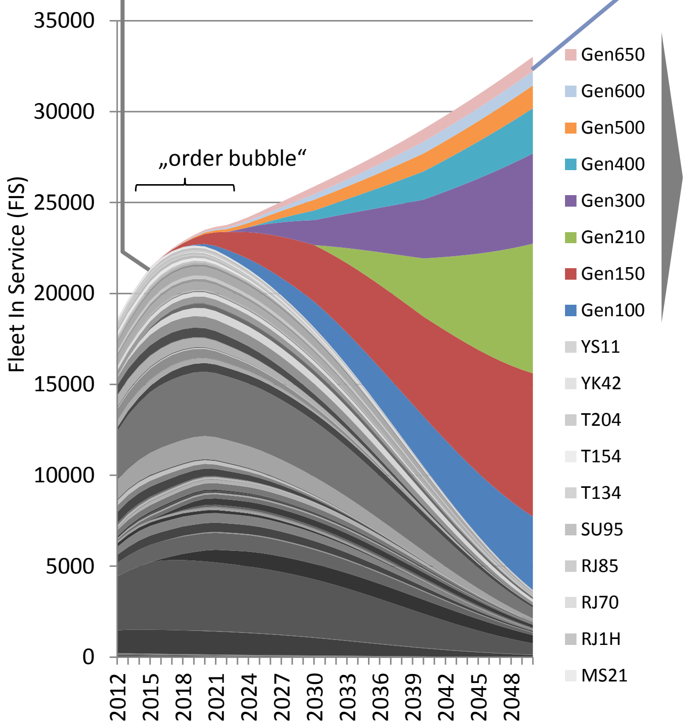
number of flights by seat category and by generation of aircraft

DLR

Outlook: World Fleet renewal & networks

Specific und generic aircraft

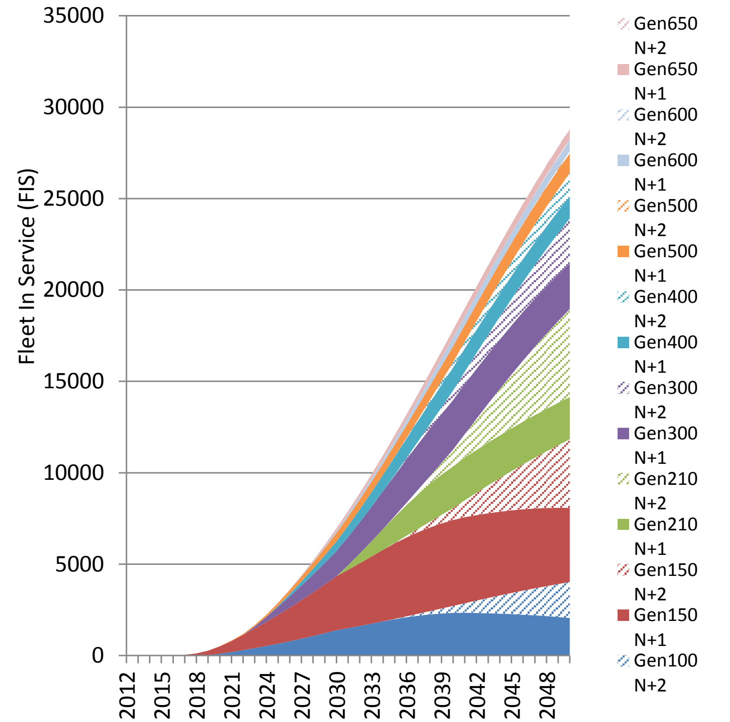
„fixed“ aircraft
Current fleet & orders
Specific aircraft
aircraft types (ICAO-Codes)
grouped by seat categories
Generation N and N+1



New aircraft concepts: unfixed aircraft

„unfixed“ aircraft
generic aircraft
no aircraft types
N+1, N+2, … according to EIS

New aircraft concepts are applicable only to generic subffleets according to their EIS and seat category.



DLR

city pair demand network 2012
connections > 100k PAX

Thank you for your attention.