SEVENTH FRAMEWORK PROGRAMME (FP7)

CARGOMAP

AIR **CARGO** TECHNOLOGY ROAD **MAP**

Project number: 284551

D3.3
Air Cargo Technology Roadmap
Synthesis and Recommendations

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1 Executive summary

Main goals of the CARGO Map (CSA-SA) project were:

- Analysis of current situation in air cargo and the demand with the involvement of the stakeholders in Europe.
- Expected future bottlenecks/challenges in air freight transport and the identification of the corresponding requirements. The requirements will identify the technology needs and regulatory issues to be addressed.
- Synopsis and evaluation of possible improvements related to future business models and business cases.
- Definition of a technology roadmap to fill the technology/regulatory/operative gaps in order to fulfil the requirements considering the current capabilities.

The project aim was to investigate what new challenges and opportunities exist for new air cargo aircraft in the future, responding to societal challenges and the concept of seamless multi modal transport chains.

Based on business cases, the possible need for novel dedicated air cargo planes has been derived and the technologies that will be needed to create these novel airplanes have been identified in the roadmap.

Whilst identifying novel technologies, only those specific to air cargo vehicles and operations are shown in the roadmap, assuming that the generation of generic new technologies in aviation will take place.

Current and planned research activities have been identified together with the missing elements to enable a new generation of air cargo aircraft to be developed between 2030 and 2050. Such a roadmap on a European scale does not exist for dedicated cargo planes.

Each activity was developed in a specific task and WPs and the results are presented in specific deliverables.

The Roadmap document is collecting all the results in a single self-standing report, referring to the specific deliverables for detailed analysis. The roadmap is being proposed to the European Commission, the private industry, Member States and networking organizations like ACARE to select research and technology topics for future cargo aircraft RTD projects and prioritize funding.

The present document is thus providing a summary of technology roadmap main achievements and conclusions.

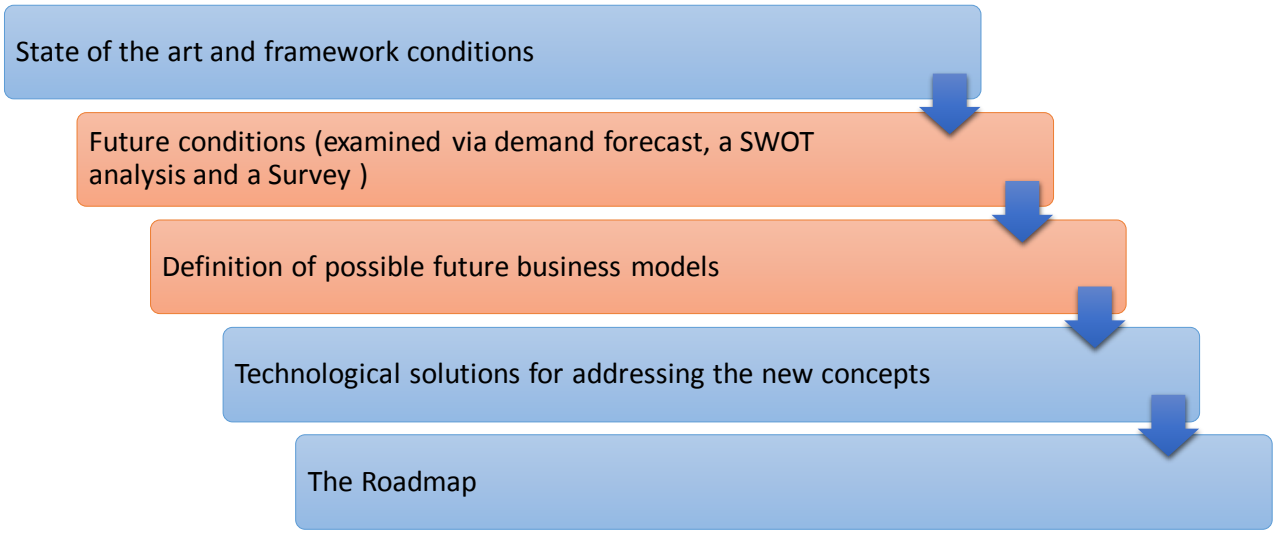
The development of the future Air Cargo industry should get the attention of the EC considering the importance of a competitive transport system for the European social welfare and the industrial leadership.

An optimal air cargo business approach and efficient cargo aircraft might reduce the environmental impact of European cargo transport.

2 CargoMAP Project – Summary

The Air Cargo technology Roadmap (CargoMap) project focused on the future role of air freight and the definition of a technology roadmap for future cargo aircraft responding to end user requirements and environmental needs.

The project approach was as follows:



Novel concepts in aviation need a long time to mature. So it is appropriate to develop a technology roadmap aimed at future technologies specifically related to novel air cargo aircraft.

The main aim of the project was to prepare a RoadMap identifying specific enabling technologies and operational issues and at what time this will be needed. The focus was on technologies specifically aimed at air cargo operations and the dedicated air cargo aircraft even though reference is made also to generic technologies in aviation. Time focus is 2035 as in the SRIA, including a perspective towards 2050.


3 Introduction

This document is a synthesis of the Roadmap document and concluding recommendations.

The Roadmap is providing a collection of main achievements of the CARGOMAP Project and the technology roadmap derived with a specific approach:

- investigate challenges and opportunities for air cargo operations in the future, responding to societal challenges and the concept of seamless multi modal transport chains;
- study the current business models and provide alternative business cases for new types of air cargo operations;
- define new requirements for novel air cargo planes;
- identify the technologies that will be needed to create these novel airplanes in addition to the technologies that are already planned for civil airliner developments and ATM.

The Cargo Roadmap document is structured according to specific steps.

- Overview of the Air Cargo Industry in terms of transported goods' types and existing stakeholder categories (integrators, airlines, manufactures, etc.), current business models and possible new approaches.
- Forecasted air cargo demand and future trends for short/medium/long haul and domestic service for different commodities.
- Highlights from Flightpath 2050 with a special focus on the goals and enablers for the Air Cargo.
- Description on the approach to develop the R&TD roadmap.
- Vision for the air cargo in the future ATS for 2020, 2035 and 2050.
- European and international scenario for air cargo industry and R&TD activities.
- Air Cargo Roadmap for the medium term (2035) and for the long term (2050) looking to:
  - Products and Technologies;
  - Business Models and Operations;
  - Enabling Conditions.

In this document only a synthesis of the CARGO Roadmap and main conclusions are provided for a quick reading.

4 Flight Path 2050: A Vision for the ATS of the Future

The Aviation community agreed to establish the European Technology Platform, ACARE, in order to sustain the goals of the Vision 2020 for Aeronautics, and developing strategic research agendas (SRAs) implemented through outstanding research projects in FP7.

The vision and its ambitious goals are largely recognised by the aviation community including Member States and the European Commission. In response to this document, the European Technology Platform for Aviation, ACARE defined a new strategic agenda for aviation research and innovation (SRIA) providing the enablers, and the capabilities needed to reach the goals set out in Flightpath 2050, together with the required research and technology activities to develop the concepts, systems and services of the future ATS and cross-modal requirements.

This agenda should form the basis of all Research, Technology and Innovation activities performed in Europe.

In the SRIA some important objectives are also defined for air cargo. These can be summarised as follows.

- Maintaining industrial leadership.
- Freight shippers can make informed choices to select optimal multi modal transport options
- Unmanned systems are an important way to transport air cargo.
- Seamless transport chains will allow air cargo within Europe to reach door to door destinations within 4 hours
- New emission standards like 75% reduction of CO2 per FTK, 90% NOx reduction and 65% noise reduction compared to the year 2000.
- Recycling of aircraft and emission free taxing.
- Safety target is less than one accident per 10 million flights.
- Security will have a minimal impact on seamless transport flows.
- The air transport system is resilient to external hazards.
- Flights arrive within one minute of the scheduled arrival time and the capacity of the European airspace allows for at least 25 million flights.

The new SRIA will be the reference for national, industrial and European priority setting of future research efforts.

The Air Cargo Technology Roadmap is meant to complement the SRIA for specific Air Cargo needs.

5 Alternative Business Models for Air Cargo

It is important to point out the air cargo industry extends well beyond air carriers.

The global air cargo operating system is characterized by a network of relationships among carriers, brokers, handlers, motor carriers, integrators, airports, freight forwarders, customers, suppliers, manufacturers and logistics service providers.

The overall air cargo transport network of professions is presented in figure 1, and each profession depends upon the other for its growth and survival.

Moreover, today's air cargo environment is becoming increasingly integrated and ground-linked, characterized by door-to-door service from shipper to customer, as opposed to airport-to-airport.

Time-definite services are also becoming expected by supply chain members making it imperative that all key players operate in an integrated, reliable fashion.

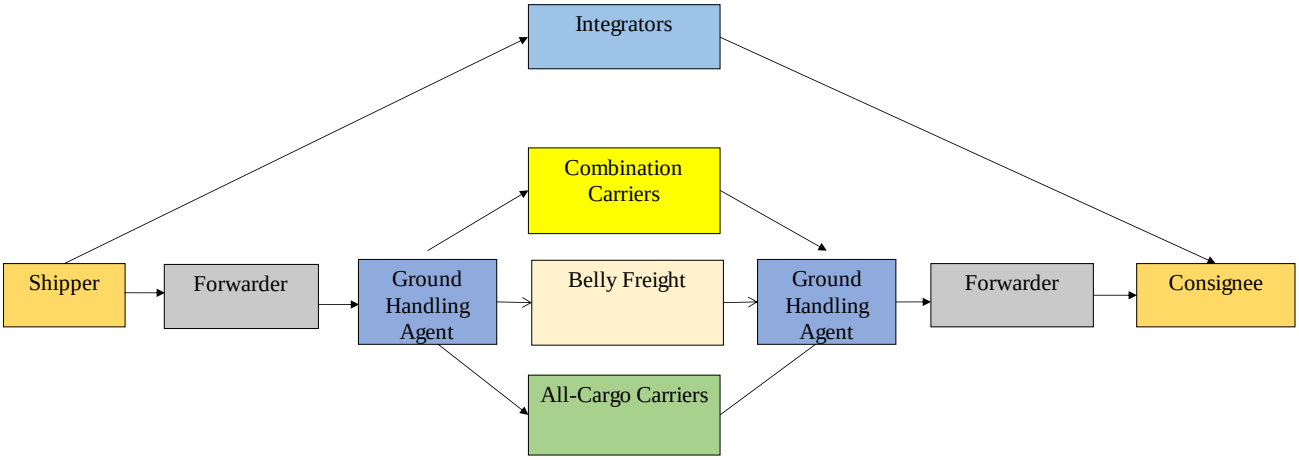


Figure-1: Key Players in the Air Cargo Market
Source: Kasarda et al. (2004),

6 Air Cargo SWOT analysis

What must understood is the position of air cargo in relation with other transportation means. Air cargo offers a premium product with high speed, high reliability, that can compete with surface transport. Air cargo is however more expensive.

Transporting goods by air is characterized by two main advantages:

- Speed advantage
- Geographical and infrastructural constraints.

A SWOT analysis of the Air Cargo is provided in the table 1 providing a synthesis of

- Strengths
- Weaknesses
- Opportunities
- Threats

Air Cargo	*Positive factors*	*Negative factors*
Internal factors	**STRENGHTS** • Speed • Security and safety • Reliability • **No path congestion** • Low external costs • Low land occupancy • No competitor for high value goods on the long ranges	**WEAKNESSES** • **High cost** • **Not intermodal** (how to include "the box"?) • **Spatial mismatch in the door-to-door chain** (→ remove the need of using inland terminals?) • Weak economics of most carriers •Under-representing of the Cargo sector in policy making processes
External factors	**OPPORTUNITIES** • Long run **growth of economy and trade** (esp.LDHV goods) • **Liberalisation of the market** (more carriers allowed in more areas) •Globalization of procurement, production and distribution • **Urban population growth** and new logistics concept • New technology	**THREATS** • Fuel costs • External shocks • Security issues and requirements • Airport congestion • Night restrictions • New business models from competing modes

Table 1 - SWOT Analysis of Air Cargo

In the Air Cargo Roadmap [1] more details are provided about the SWOT analysis for Air Cargo but also for other transport modes.

7 Air Cargo Demand

Both Airbus and Boeing make efforts to forecast future cargo demand. Boeing publishes their results once every two to three years, while Airbus usually publishes in general more often, the latest version of its forecast was published at the end of 2011 (Airbus, 2011). The Boeing report of 2009, shows in a clear way all negative and positive effects on air cargo traffic growth. In synthesis:

- Airbus and Boeing predict an average annual growth of about 5%, mainly on long haul.
- 800 new freighters are foreseen.
- Boeing expects inter European cargo traffic to grow by 2.4% annually.

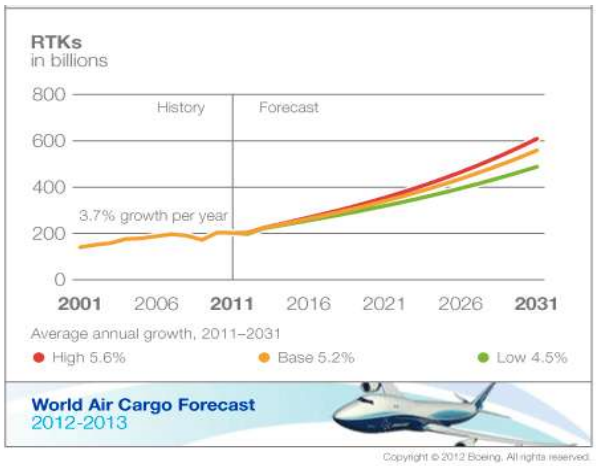


Figure 2: Boeing Forecast for Air Cargo

Figure 1: Influencing factors
Source CARGOMAP

Figure 3: Influencing factore of Air Cargo Business

Air freight is essential for a variety of industries that require transport of time-sensitive commodities.

More specifically the types of goods in Air Cargo are here listed:

- Perishables
- high-value, low-weight goods including consumer electronics
- high-fashion apparel
- Pharmaceuticals
- industrial machinery
- high-value intermediate goods such as auto parts

In Figure 4 Air Freight commodities share in 2008 is presented.

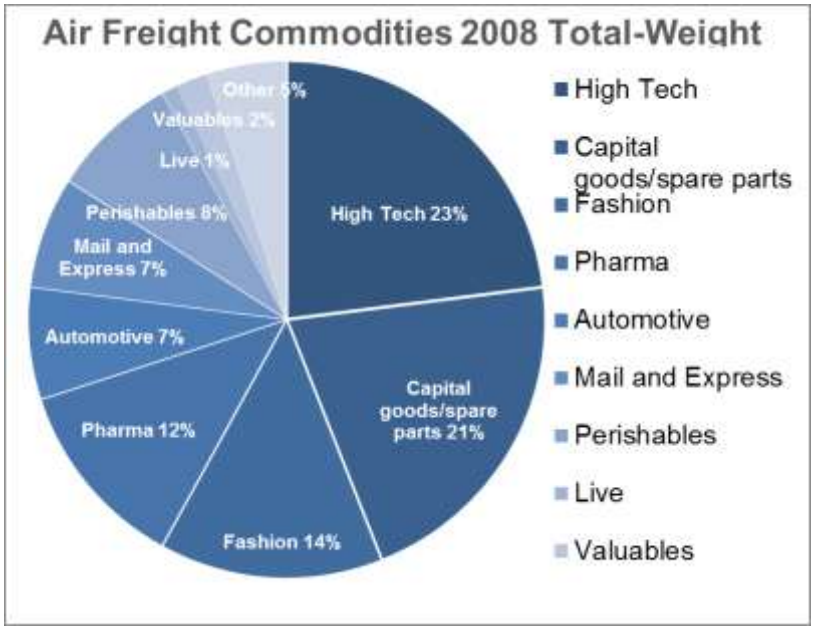
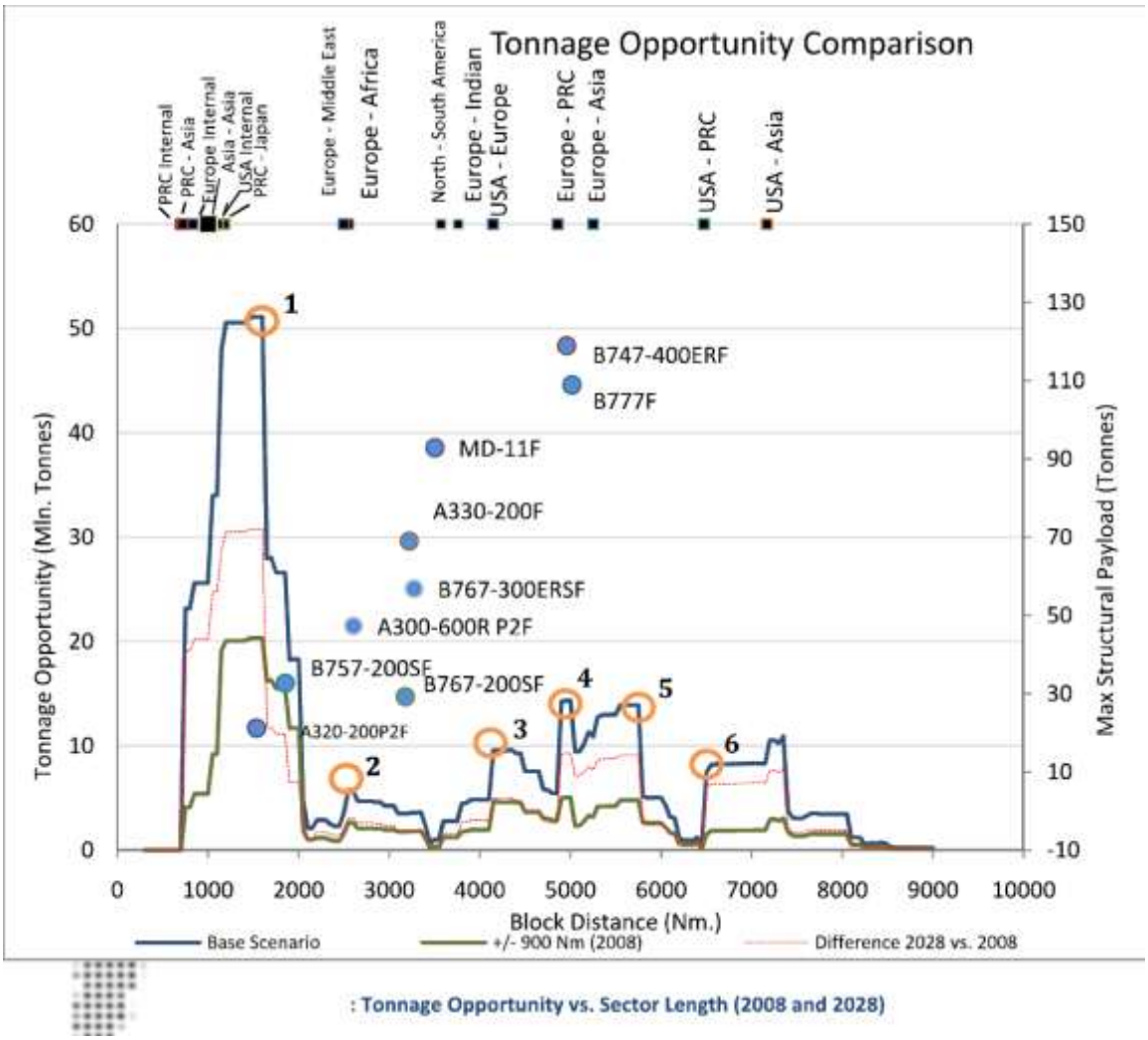


Figure 4: Air Freight commodities share in 2008

In the frame of the CargoMap project TU Delft published a market forecast for 2028.

The forecast focused on transport range and the result is shown in figure 5.



: Tonnage Opportunity vs. Sector Length (2008 and 2028)

Figure 5: Tonnage opportunity comparision

The analysis shows a substantial growth potential also on short haul routes.

However, on this segment transport needs to compete with trucking on short haul. As trucking is about 50 times cheaper than short haul air transport, the challenge for short-haul air cargo is to design an aircraft that would be faster and substantially cheaper to operate then currently available.

Another forecast by Carlier (2011) discusses several tonnage opportunities for different range characteristics. This forecast distinguishes several peaks of which the two most important are discussed below.

1. The first and by far largest peak in tonnage opportunity is for the short to medium range markets up to approximately 1,600nm. This is due to the fact that many of the large internal markets are situated within this range, as well as the very large transportation flow between Asia and the People's Republic of China (PRC). The reasons for the size of this peak are mainly due to the high growth expectations for China and to a lesser extend due to some other Asian countries.
2. The second big tonnage opportunity can be defined for a range between 4,000 and 6,000nm, which includes all routes between North America, Europe, and Asia, and the PRC respectively.

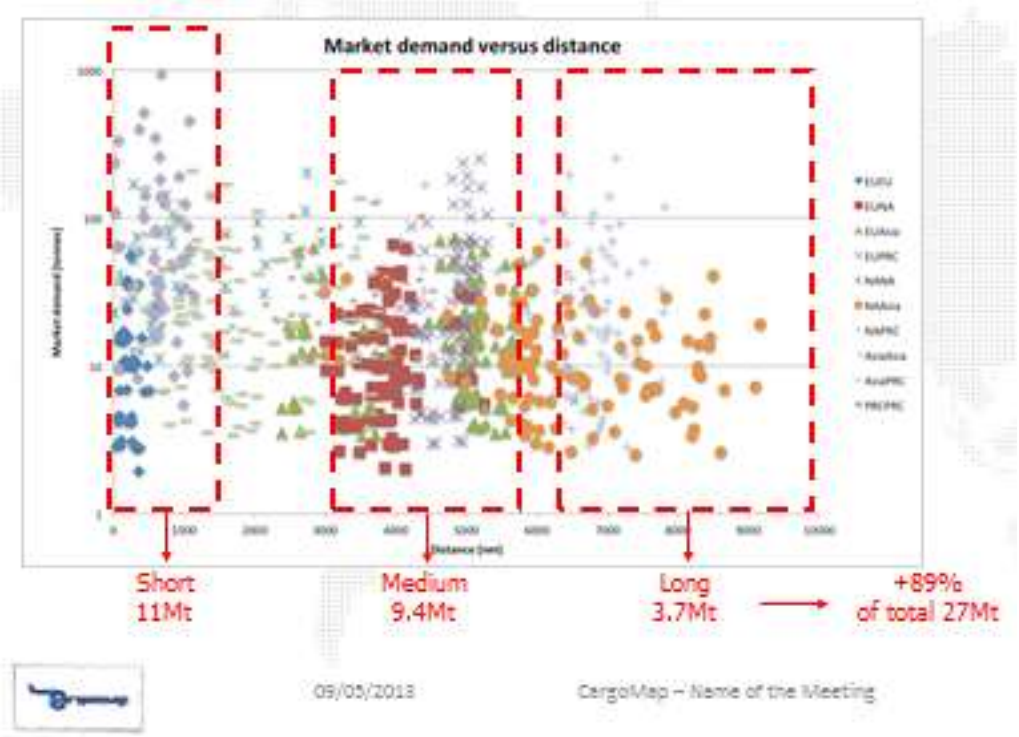


Figure 6: Market demand versus distance

7.1 The CargoMap forecast for Europe

The construction of a baseline scenario was aimed at quantifying the overall amount of goods transported in the future time horizons (up to 2050) in order to define the volumes at stake in the competition between modes of transport.

As an attempt at the defining an "as is" scenario, the baseline scenario elaboration adopts a comprehensive approach that relies on a combination of projections of historical trends and forecast which take into account the global outlook of main economic drivers.

The figures below show the past trends in EU-27 transport demand from 1995 to 2010. The transport demand is measured in terms of tonnes kilometre for freight transport by transport mode.

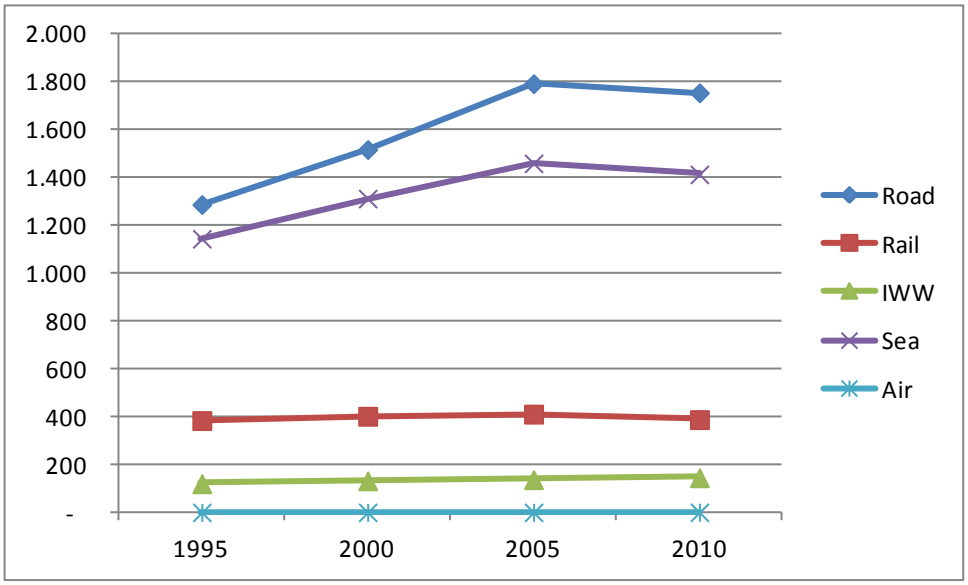


Figure 7: EU27 freight transport by mode, 1995-2010, thousands mio tkm
Source: Consortium elaborations on Eurostat data

The overall goods transported (pipeline transport is excluded) have therefore increased from a total 3060 thousands mio tonne-kilometres in 1995 to 3499 in 2000, to 3946 in 2055 and to 3831 in 2010, after a peak at 4173 thousands mio tkm in 2007, with an average growth of 1.5% per year in the 15-year span. In the last period, as evident from the chart, due to the deep economic crisis, the total volume of goods has decreased.

The consequent historical trend projection, which is calculated on the overall transport of goods regardless of transport modes, is presented in the chart below.

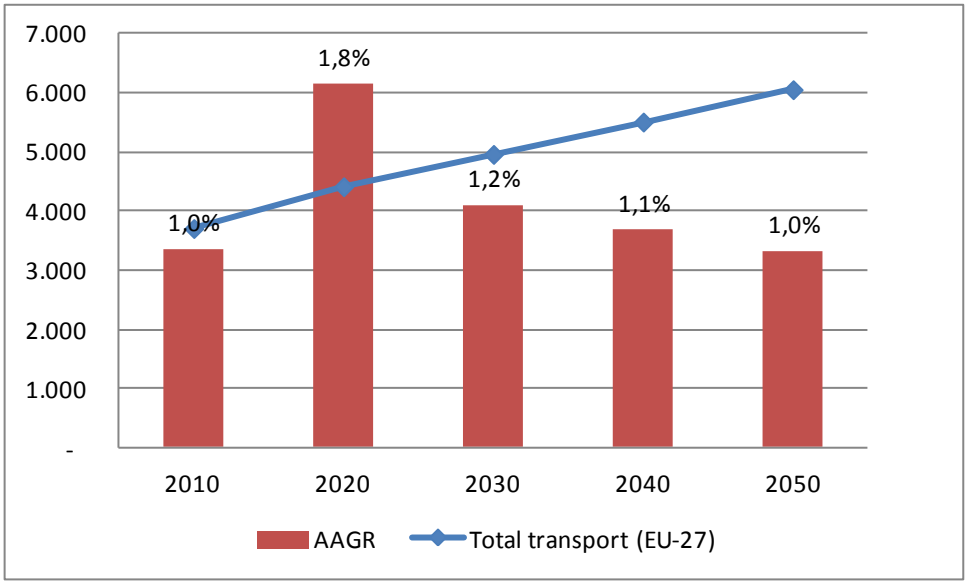


Figure 8: EU27 freight transport, historical trend projection to 2050, thousands mio TKM and AAGR
Source: CARGOMAP elaborations

On the other hand, available forecasts for global trade asses that world trade (defined as the sum of world exports and imports of goods and commercial services) is set to expand at an average rate of 6.1% p.a. between 2010 and 2030, and by 4.4% p.a. between 2030 and 2050.

In terms of geographical markets, the expectations for Europe in terms of growth rates of total trade are therefore as follows.

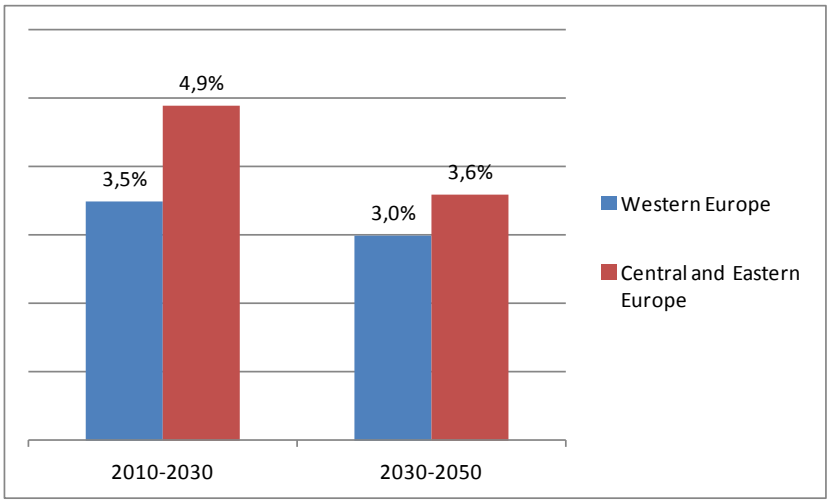


Figure 9: Europe's global trade long term growth rates
Source: CARGOMAP elaborations on Citi GPS data

Considering the two types of forecast as a prudential and optimistic scenario respectively, we elaborate a baseline scenario based on the current transport volumes, the historical trends of tkm and the trade outlook, which assess the overall tkms transport to/from and within Europe at 6319 billion in 2030 and 10109 billion in 2050.

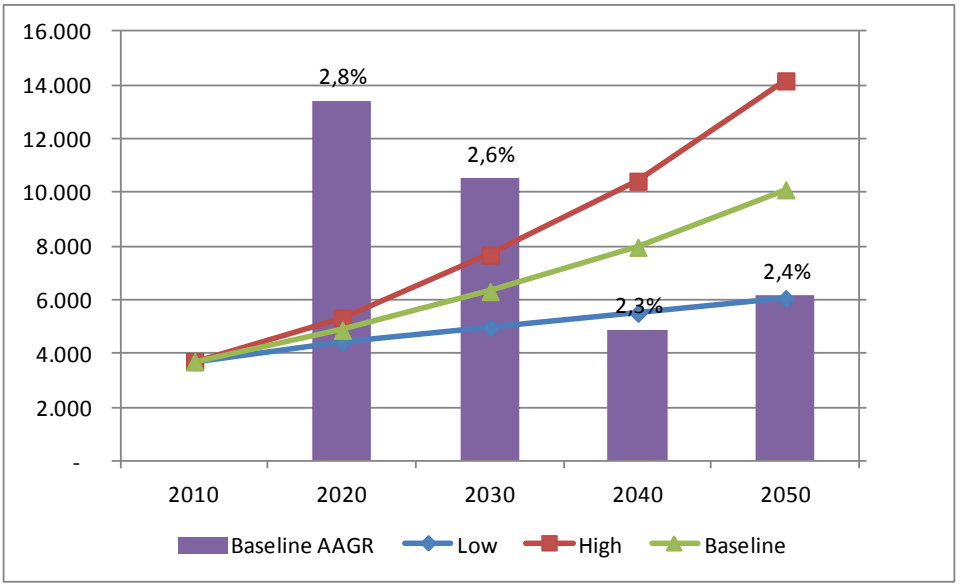


Figure 10: Baseline scenario of freight transport for Europe, 2010-2050, thousands mio tkm
Source: CARGOMAP elaborations

This result is consistent with the assessments of the recent TRANS vision study (2009), which expects freight traffic in EU-27 to grow annually by 2.0% to 2020, 1.9% to 2030 and 1.4% to 2050 – taking into account that this forecast (lower than our baseline scenario) only includes transports within EU-27 and with neighbouring countries.

A word of caution: Experience has shown that all forecasts need to be treated with some caution. There may be unforeseen factors that will results in discontinuities. The recent experience has shown he situations as in figure 40.

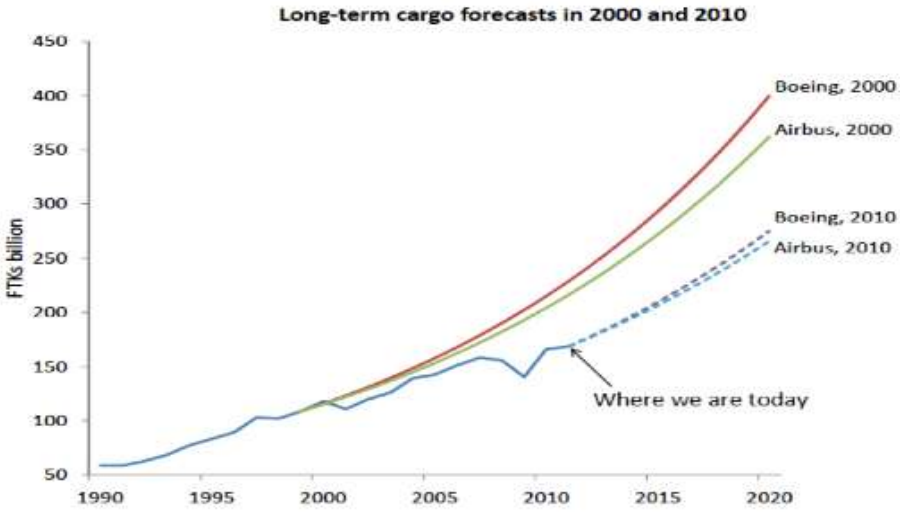


Figure 11: Long-term forecast in 2000 and 2010
Source KLM

8 VISION for AIR CARGO in FUTURE ATS

A vision of the air cargo development is presented in the Air Cargo Roadmap [1] for short (2020), medium (2035) and long term (2050); in the following a synthesis is provided looking to two periods: 2020, 2030 and beyond.

8.1 VISION FOR THE SHORT TERM (2020)

8.1.1 Key elements

- No major changes expected
- More efficiency in door-to-door-business is needed : improvements in the processes of the air cargo supply chain is required; new technology is needed.
- Air transport recover from downturn may result in a stronger share of belly cargo with respect to full freight, with the network carriers focusing on intercontinental routes.
- E-commerce growth impact on forwarders and shippers.

8.1.2 Competition

- Competition will stay fierce. New carriers from the ME, China and Turkey will set the price.
- Cargo operators will try to further reduce empty legs by flying to different locations during the same trip.
- Parcel services are likely to grow.
- There may also be a shift in types of goods transported on long haul routes.
- Any significant change on medium or short haul cargo transport is not expected due to competition from trucks that will be difficult to beat.
- Despite all efforts to increase rail cargo, it is unlikely that there will be a substantial shift to rail as the capacity of the rail system is limited and high speed rail connections may be completed much later than expected as a result of the economic crisis. Already a number projects for high speed rail connections planned in Portugal and Poland have been stopped.
- E-commerce will be further developed which will also mean a strong impact on forwarders and shippers. Paperless shipping and “smart gate “concepts are expected to be implemented which will reduce time spent at warehouses for goods.

8.1.3 Modal shift

- No substantial modal shift is expected.

8.1.4 Aircraft

- No new aircraft are expected in the near term.

- Up to 4 years ago it was expected that Airbus and Boeing were to launch an all new aircraft as a successor of the A320/ B737 aircraft family. Several concept studies were made. Novel engine concepts were investigated including the un-ducted fan. These aircraft were supposed to be ready by 2020.
- In reality, these companies have decided to install improved engines on the existing aircraft models and to continue the production of the A320 and 737 as 320 NEO and 737 Max.
- On the long haul market the derivatives of relative modern aircraft like the A330/350 and B777/787 will dominate the market.
- On the medium haul there will be derivatives and conversions as well.
- In the short haul market we may see new small efficient aircraft to be introduced. The current Piston powered aircraft like the Cessna Caravan, PC-12, BN Islander etc. may start to be replaced by more modern aircraft for short haul traffic if a suitable new engine can be developed.

8.1.5 Regulation

- In 2016 the EU should put a new regulation should be in place to enable the use of remotely piloted air vehicles in the European airspace.
- However a serious attempt to replace courier services with autonomous UAS is not expected before 2020.

8.2 VISION FOR THE MEDIUM TERM (2035) AND BEYOND (2050)

8.2.1 Summary

- High risk of economic shift to the East: Aircargo hubs might move their centre. This calls for improving competitiveness of air cargo market and industry in Europe
- Risk that lower value high tech goods shift to other modes; new products requiring air cargo should be pushed to exploit air cargo.
- A new regulation to allow UAS and new technologies up-take should become available.
- …Could safety requirements drive regulation against belly cargo?
- Time constraint goods might take the biggest share of air cargo in 2030.
- Innovative technology is needed for a step change in aircraft products: these new technologies and products should be in a validation/demonstration phase.
- Some new aircraft might be introduced for Medium and Long Haul.
- For Medium and Short the use of regional airports and V/STOL innovative aircraft will be a welcome addition to road transport.
- There may be more hybrid transport solutions. For this concept standard containers will be needed.
- Starting from around 2035 air cargo aircraft could be operated without pilots. It is assumed that the technology is available to make safe and secure pilotless aircraft.

- By 2030 the gas turbine technology will be totally mature. Other engines will be developed (e.g. super conductive electrical engines) that will start to power part of the fleet.
- Bio fuels will be more affordable and a welcome addition to kerosene. The most promising biofuels will be based on algae production as the feedstock of other (cellulose or sugar based) sources will be very limited assuming no food production for humans is endangered. Algae based biofuels need to become substantially cheaper to be attractive however.
- Sufficient funding should be available to do research and to design and manufacture novel aircraft.
- Global standards enable the development of novel vehicles. Regulation is to be easily adapted to new technological developments.
- By 2030 the SESAR technology for ATM should be mature. It is based on trajectory based control for air traffic control.
- The regional market for aviation will be growing as road congestion may favour air transport. Novel designs in VTOL and STOL aircraft may be introduced.

8.2.2 Competition

- A change of economic condition may be expected in the different macro blocks, with a change of air cargo networks and flows.
- The intensity of cargo flows may change as economies evolve; in the figures below the intercontinental cargo flows are represented for 2011 and as expeted for 2030.

Figure 12: intercontinental cargo flows for 2011 and for 2030
Source: "Agility Logistics"

- The world population will more and more be centred in big cities, a trend that has been going on for some time now.
- Possibly the shift in economic centre will have shifted more to China and India with South America and Africa being good runner ups. Still the US and Europe will be able to continue a strong economic position based on innovative designs and technology. As China becomes more expensive due to the increase in salaries, some production will shift back to the USA and Europe. This production will be highly automated and cost efficient using robotics. This production will still require regional distribution in Europe.
- Competition will come from new IT options. Still it is expected that with increasing wealth, the parcel services will grow.

- 3D printing may result in less capital intensive goods having high priority as assumed in the fore mentioned Bauhaus study. But at the same time constrained goods may increase.

8.2.3 Modal shift

- A real modal shift is not expected although intermodal transport chains will be more important. The inflexibility of rail transport will created less competition than is expected by some. The use of regional airports and V/STOL (Vertical/ Short take-off and landing) aircraft will be a welcome addition to road transport.
- There may be more hybrid transport solutions. For this concept universal containers will be needed.

8.2.4 Aircraft

- For new aircraft development a specific section is dedicated in the Air Cargo Roadmap and a synthesis is provided in section X.Y of the present report.

8.2.5 Regulation

- New regulation should be in place for a fast adoption of innovative technology into new products.
- A threat could be the discussion about the use of belly freight for safety reasons. If a new regulation will not allow the use of belly freight this will imply a real shock for air cargo industry and a complete change of business models and fleet reorganisation will be needed. This will have an impact also on passenger transport aircraft.

8.2.6 Possible future business models

In Figure 13 possible future business models are presented and explained in Figure 14

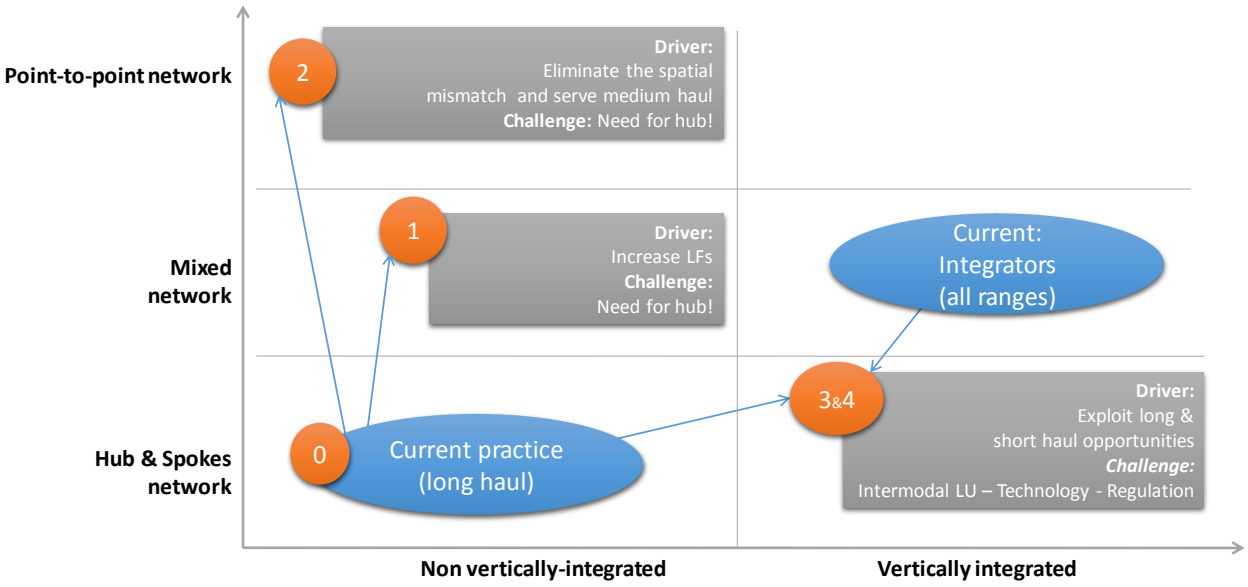


Figure 13-a: Possible Future Business Models

0 Maintaining the current business model: shippers/forwarders contract transport operations with cargo carriers and provide pre/post-haulage to/from **"hub" terminals which are connected by long haul air cargo operations**. Cost optimisation (both direct and indirect costs) would be the only aim in order to attract new commodities.

1 Adapting the current business model for gaining higher load factors (attracting lower added value goods as well), so that **point-to-point routes** could also be added to the (traditionally hub&spokes) network;

2 Center air cargo operations on **regional airports and point-to-point routes** (deriving requirement: to avoid the technological/economic need for concentration into hubs).

- Centre air cargo operations around **carriers which can manage the whole door-to-door chain** (as integrators do nowadays). Deriving challenge: **increase intermodality for a seamless flow of cargo**: introducing an intermodal LU into the air cargo operational model. This would allow to operate the current business model on the medium haul as well.

- Exploit the growth of e-commerce and urbanization with concepts that enable **air transport in the very short haul.** New types of ATC and liability schemes would be needed. A low noise foot print is required.

Figure 13-b: Possible Future Business Models

9 Air Cargo Roadmap

The Air Cargo Roadmap is structured as follows:

- Innovative Air Vehicles to serve the future air cargo market
- The Research Roadmap
- The Issue of a new air cargo container
- The synchro/inter-modal initiatives

A clear reference to the short (2020), medium (2035) and long (2050) term is provided for the proposed air vehicles and research topics.

Here below a synthesis is provided providing the main elements; it is recommended to see the complete document for details and especially for the research topics.

9.1 Future aircraft configurations

9.2 Innovative air vehicles to serve the future air cargo market

Cargomap identified a number of possible future aircraft configurations and selected the preferred solutions based on a qualitative assessment based on cost, door-to-door-time and frequency of service.

- Long haul
- Medium haul
- Urban delivery

CargoMap has identified 18 different types of aircraft configurations that could serve the air cargo market starting from 2030.

Here, the qualitative evaluation is made assigning to each parameter a value ranging from “----“up to “+++”.

The proposed evaluation can be improved in future by providing the scoring on the base of some computation instead of quantitative evaluations.

Type	Speed focus	Cost focus	Frequency focus	Remarks
Long haul				
Very large WIGE aircraft, payload 680 tons				Could also be an amphibious aircraft
Very large subsonic aircraft, payload 300 tons				Also for outsize cargo requirements
Novel subsonic aircraft based on BWB technology, payload 100 tons				Same speed as today but at reduced cost. Use of standard containers. Should be developed into a family concept.
Slow flying aircraft with payload of 100 tons				Will be very environmentally friendly
Supersonic cargo aircraft				Speed range could go from M1,3 up to M 2,5
Hypersonic air cargo aircraft				Could fly between Mach 5 and 8
Morphing subsonic aircraft able to perform formation flights				Aircraft would be able to fly in close formation of a few wingspans
Small aircraft that could be joined in flight to gain fuel efficiency and allow small cargo volumes to be delivered				Aircraft would depart at different locations, join up in the air to create an efficient large flying body and leave the formation near to the destination
small aircraft with intercontinental range				Aircraft would fly dedicated to high value cargo

Table 2 Alternative Long Haul Aircraft

Type	Speed focus	Cost focus	Frequency focus	Remarks
Medium / short haul				
10. New large medium haul aircraft with > 100 tons capacity				
11. Large Airship				Type of HULA airship
12. New regional air cargo aircraft with a capacity of 50 tons				
13. Tilt rotor aircraft with a capacity of 20 tons				The speed would be improved due to an almost door to door delivery
14. Advanced rotorcraft with payload of 10-20 tons				Make use of advanced VTOL/STOL concepts The speed would be improved due to an almost door to door delivery
15. Advanced small aircraft				Could make use of fanwing concept
16. Advanced small aircraft				10 tons payload
17. Replacement of Cessna caravan type of aircraft				4 tons payload
Urban flying vehicles				
18. UAS systems				

Table 3 Alternative Long Haul Aircraft

9.3 Ranking of alternative aircraft

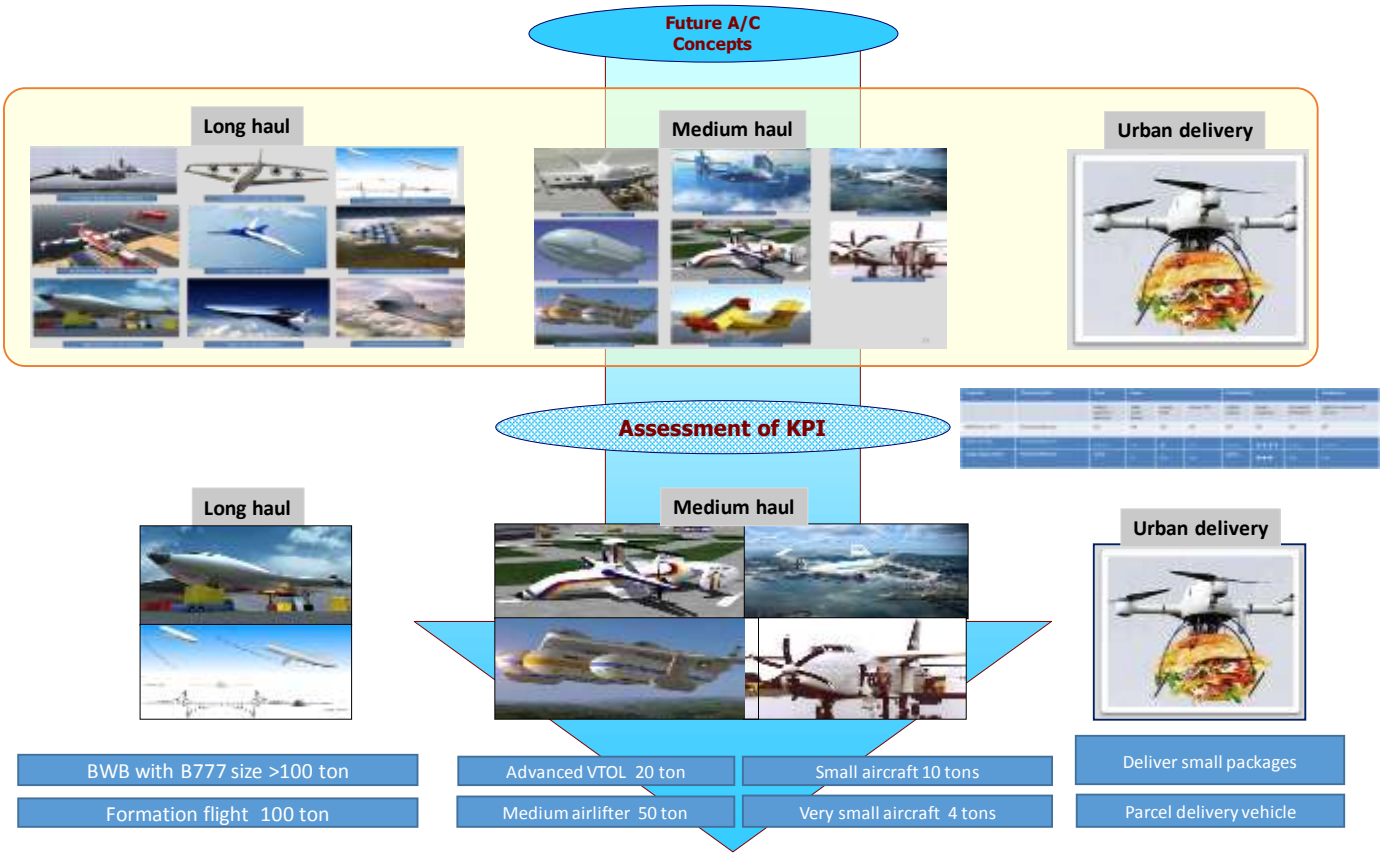


Figure 14: The ranking process and outcome for future cargo aricraft

Figure 15: CARGOMAP ideas for future cargo aircraft

9.3.1 Long haul cargo aircraft

As already indicated the air cargo market is influenced by GDP development (elasticity 2) as well as cost, time and frequency of delivery. Furthermore, there is the issue of environmental impact. This element is difficult to quantify as no elasticity is known. If ETS is introduced the environmental impact could be expressed in terms of cost. As already indicated previously, the elasticity for price is about -1, the elasticity of time to delivery is about 2 and no clear elasticity was found for frequency. This is supposed to be 1 as well.

Proposal	Characteristics	Time	Cost			Productivity			Frequency
		Higher speed to delivery	High Load factor	Lower DOC	Lower IOC	Higher Speed	Larger Capacity	Increased Utilization	Higher Frequency of service
Reference 8777	Payload 100 tons	ref	ref	ref	ref	ref	ref	ref	ref
Wige aircraft	Payload 680 tons	----	--	+	--	----	++++	---	----
Large cargo plane	Payload 300 tons	same	-	--	--	same.	+++	--	--
Efficient cargo plane	Payload 100 tons	+	+	+++	++	Same	+	+	same
Slower aircraft	Payload 100 tons	+/-	Same	++	same	--	same	same	same
supersonics	Payload 50 tons	+++	--	-----	--	+++	--	++	+
hypersonic	Payload 50 tons	+++	--	-----	---	+++	----	+	+

Table 4: Result of assessment - Long haul cargo aircraft

Taking the qualitative assessments into account, the ranking for the proposed long haul cargo is as follows:

1. BWB
2. Formation and coupled flight
3. Supersonic aircraft
4. Flying slower/ lower
5. Very large aircraft and WIDGE
6. Small aircraft
7. Hypersonic transport

9.3.2 Medium/ short haul cargo flights:

On the short haul the competition is from Trucks. Price is the most important issue.

Proposal	Characteristics	Time	Cost			Productivity			Frequency
		Higher speed to delivery	High Load factor	Lower DOC	Lower IOC	Higher Speed	Larger Capacity	Increased Utilization	Higher Frequency of service
Reference A320	Payload 50 tons	ref	ref	ref	ref	ref	ref	ref	ref
Cargoliner	Payload 120+ tons	same	-	+	+	same	++	-	--
HULA	Payload 500+ tons	-----	++	---	---	-----	+++ +	-----	------
Medium airlifter	Payload 50 ons	++	+	++	++	same	same	+	same
Tilt rotor	Payload 20 tons	++++	++	---	++	--	same	+	++
Advanced VTOL	Payload 10-20 tons	++++	++	--	--	++	-	+	++
fanwing	Payload 10tons	++	++	-	-	++	-	+	+++
Small aircraft	Payload 10tons	+++	+	+	-	++	-	+	+++
Very Small aircraft	Payload 4 tons	+++	++	+	+	++	---	++	+++

Table 5: result of assessment - Medium/ short haul cargo flights

Taking the qualitative assessments into account, the ranking for the proposed long haul cargo is as follows:

1. Replacement Cessna Caravan
2. New regional aircraft with 50 ton capacity
3. Large medium haul aircraft
4. Advanced VTOL (rotorcraft including the autogyro)
5. Fanwing
6. Large tiltrotor
7. Hula airship

9.3.3 Unmanned aircraft

The concept of fully unmanned flying should be developed by 2035, including certification. This would constitute a substantial cost reduction as no crew cost are needed.

If large cargo aircraft will be flown without pilot the fuselage might be unpressurised allowing different shapes and thus weight and fuel savings. There could be different structures proposed and substantial cost savings can be achieved. Although the issue seems not to alter the priority listing of the previous chapter the substantially lower cost due to the reduction of fuel cost (due to the light weight structure) and the reduction of crew cost will make air cargo much more attractive.

The fuel savings will also have a very positive effect on greenhouse gas emissions.

Note*: During the Cargomap workshop it was mentioned that future studies should set quantitative goals for the characteristics of novel airplanes.*

9.4 THE RESEARCH ROADMAP

The CargoMap research roadmap identifies research topics that need attention in the future referring to the SRIA adopted time frames 2020, 2035, and 2050. Results should be available within those time periods. Results should be mature, integrated and validated. In most cases technology demonstration is needed.

The roadmap is organised in tables. A distinction between

- operations research, and
- technology research is made.

The Tables indicate where specific research, technology and demonstration efforts are needed in addition to the ones already mentioned in the ACARE SRIA. These tables are not reported here for sake of brevity and can be found in [1]

Anyhow, it is worth mentioning some **Special RTD interest** for the 2035+

- Single pilot operations, or in the long term unmanned operations
- Pilotless flying
- Air cargo freight containers for inter-modality
- Technologies for VTOL vehicles with low emissions, noise and costs
- Safety and regulation for innovative vehicles and operations
- Improve Security for Time and Cost efficiency
- Use of smaller airports
- Noise shielding for night operation
- Insertion of new Air Cargo operations in SESAR
- It is important to support the development of new seamless transport chains. The Cargo transport of the future has to become more and more intermodal reducing road congestion and improving the overall system.
  - E-freight and the associated IT systems will be only one of the many aspects to consider.
  - A total systems approach is needed where all relevant players in the transport chain are involved.
  - Competitiveness, customer orientation, greening and cost will be prime drivers. The low load factors in transport need to be improved through clever cooperation
- Spill over effect

9.4.1 Pilotless flying

- If pilotless flight is allowed, aircraft do no longer need a pressurized cabin
- This would enable low cost alternative aircraft configurations
- Aircraft weight and complexity can be substantially reduced, saving weight, fuel and cost

9.4.2 Novel air containers

- Current aircraft containers are not compatible with containers used in surface transport
- New cargo aircraft should be designed to handle new lightweight air containers that will fit into the standard 20 feet containers used by other transport modes for seamless transport

- Containers used in air cargo need to fit in the round aircraft fuselage. As a consequence these containers are very specific and do not correspond to the standard adopted in other modes of transport.
- An alternative solution adopted for air cargo is pallets that can be stowed in big cargo aircraft.
- If unmanned aircraft would be designed specifically for cargo function in mind, the fuselage could have a different shape (e.g. rectangular). This unpressurized aircraft would be able to transport novel air containers that fit into standard surface transport containers. .
- As some freight needs a conditioned environment, novel containers, that might fit the standard 20/40 feet containers, would need to be conditioned inside. Already pressurized containers exist. Also some containers are temperature regulated. The novel container concept that is proposed should combine several characteristics and should also be adopted to surface travel.

Figure16: Novel air containers
Source AD Cuenta

- If more than one pressurized container would be needed, the unpressuzid BWB aircraft could be fitted with large pressure vessels in which the containers vcan fit. Such barrels were already developed by amongst others Delft University. These would be made of light weight composite material.

- Research into the operational benefits of such containers would be needed to see the cost benefits of the proposed solution.

Note: *The experts during the Cargomap workshop welcomed the idea of a new air container. However they also advised to keep the possibility of pallets as these can contain small packages for different customers. Containers would be interesting for big customers who need a whole container to be shipped. However the new container would need to be filled so that a high load factor can be realized.*

9.4.3 Spill over effects

It is expected that aeronautical developments will continue to:

- decrease fuel consumption and emissions (e.g. reducing drag, weight, engines),
- improve safety through new on board systems and avionics.
- Improve the ATM system (SESAR)

These developments will also be applicable for new cargo aircraft.

9.5 The intermodal transport chain

As has been mentioned in previous chapters, the cargo chains are characterized by many players, many transfer points and different functions that need to be coordinated. There is a customer centred approach missing. The customer has little real time information about the cargo being shipped, no single point of contact, no single bill and little information to influence pricing or time to delivery. The alternative of courier services exists but is very expensive as the time focus is the overall most important parameter. Although quick delivery is important for consumer goods or spare parts, the bulk of air transport cargo is time but also cost critical.

There is a need to foster research in the domain of intelligent cargo transport systems. Research is needed to understand business models of the different players, to understand how the whole logistic chain can be made more inter-connective efficiency, E-freight and travel information to enable seamless transport. The future transport infrastructure should enable seamless delivery of goods, transparency, reliability, greening and cost effectiveness. Clever governance and simplification of the transport chains is needed.

In view of the global character of logistic processes there is a need to redesign global logistics processes and enable co-operative intelligent transport systems that are based on advanced IT solutions and use the same standards.

9.6 Synchro modality

Integrators provide a door to door service by using inhouse means, like aircraft, vans and trucks. The service is fast but expensive.

Other goods are handled via shippers, forwarders (the organizer), ground transport, airport ground handling and airlines, then ground handling, forwarders, ground transport and finally receivers. Especially customers (shippers) would like to see a much closer cooperation within the transport chain. They would like to see a transparent process that is customer centred, not organisations centred. They would like to see speed, service and reliability, transparency in cost, predictability, a single invoice, information where goods are at all time, a single contact and clear agreements. They also like to see easy transfer between the players in the chain. Basically an integrated process as with cargo integrators and express service but at much lower cost. There is a remarkable ressemblance with the ideas for intermodal transport for passengers.

The demands could be met in different ways. IT technology (e-freight) could help to make the whole process transparent.

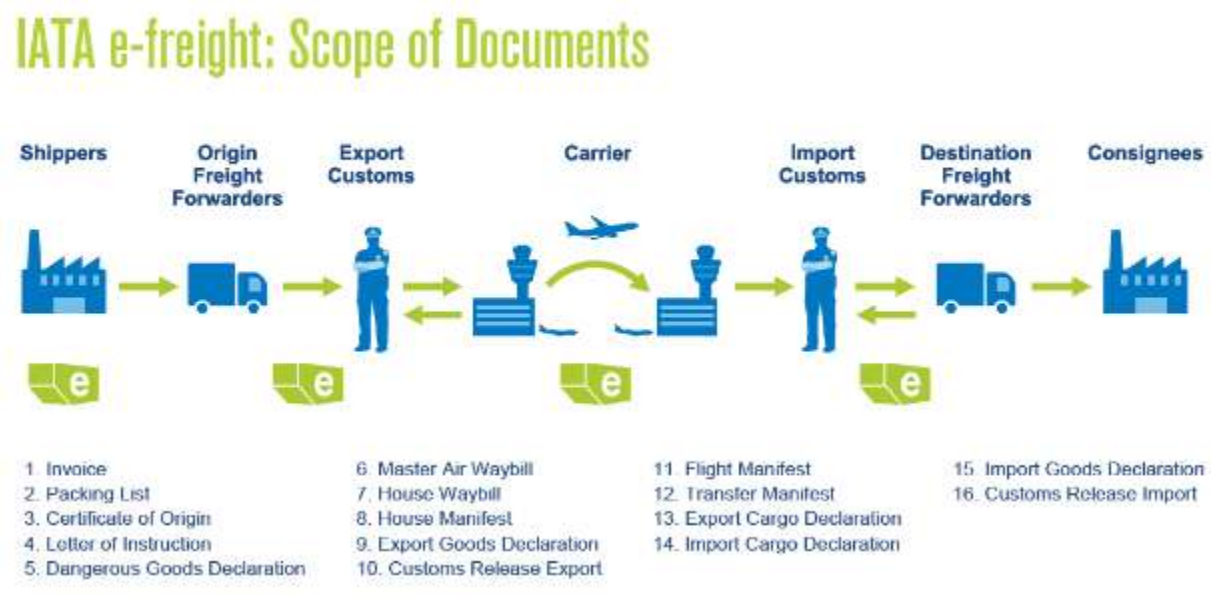
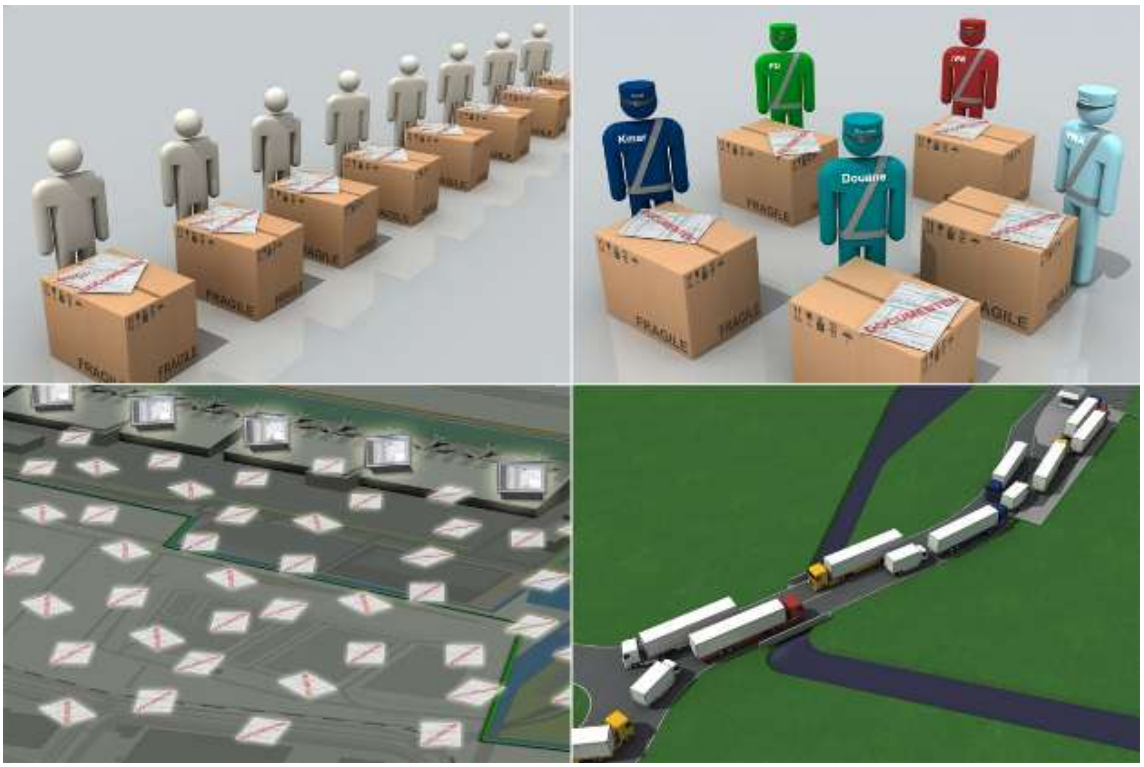


Figure 17: IATA e-freight

E-freight would also make the whole transportation chain paperless. For years it has been tried to implement e-freight in air cargo but progress is extremely slow.

There are national initiatives like the Smart Gate concept that has been introduced at Schiphol airport where bureaucracy has been reduced and government involvement of air cargo is channeled only through the customs service.



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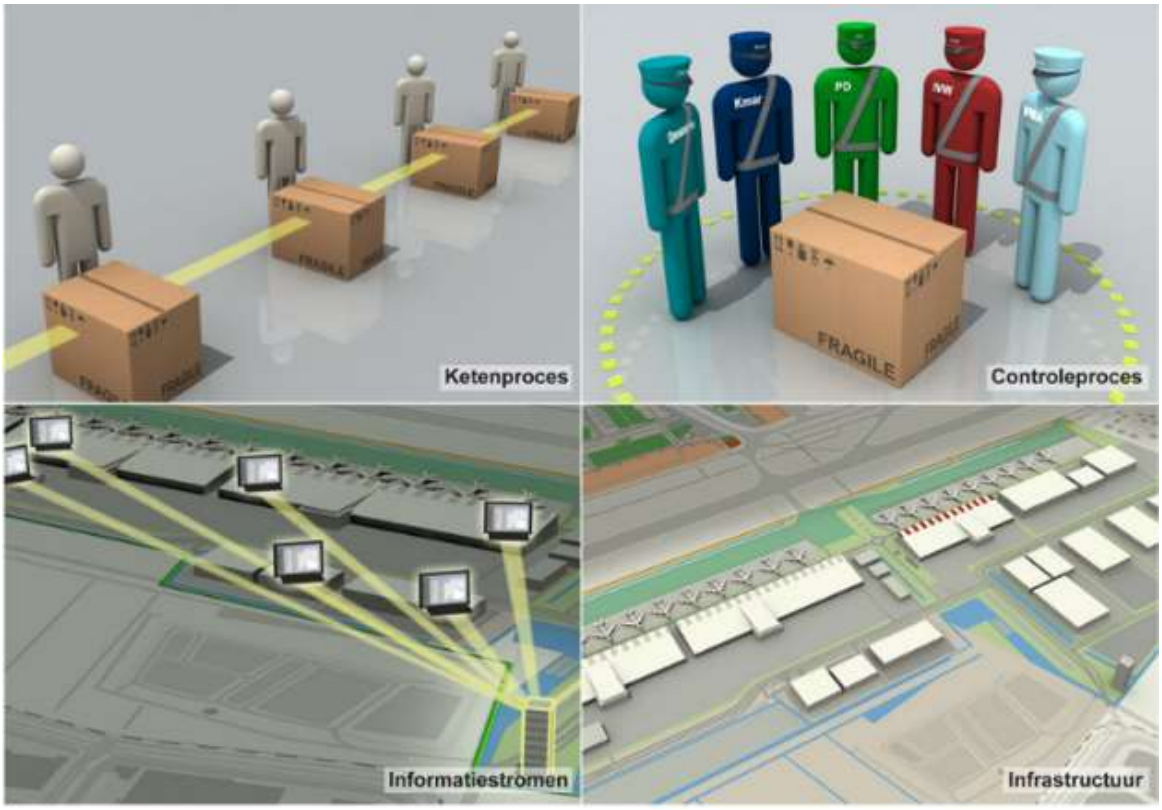


..And after.

Figure 18: Smart gate concept at Schipol airport

The idea is to rationalize the whole chain of activities to speed up the transport chain, to make it less costly and more transparent.

If e-freight is to be implemented it requires a good IT-infrastructure. It also calls for close cooperation between airlines, ground handling and trucking under the direction of forwarders. This is sometimes called synchro-modality.

The alternative is to reduce the number of players in the chain. What if airlines would integrate some of the functions and become responsible for the whole transport chain. There would be the single point of contact for forwarders and responsibility to deliver goods door to door within a certain time. In fact we already see some airlines operating their own trucking department.

(Note: During the Cargomap workshop the option to reduce the numbers of players in the transport chain was explictly mentioned by the experts. Regular air cargo operators would like to offer the same type of services as parcel service providers do but at lower prices.)Whatever solution is preferred it is obvious that should be a business case for the participants in the transport chain. And there is a need for better IT-tools. In this respect European research can help to develop European systems based on European standards. (note that intermodality in cargo may be easiere to realize than in passenger transport where there may be even more organisations involved that may not be focused on airline passengers alone and have quite different business models).

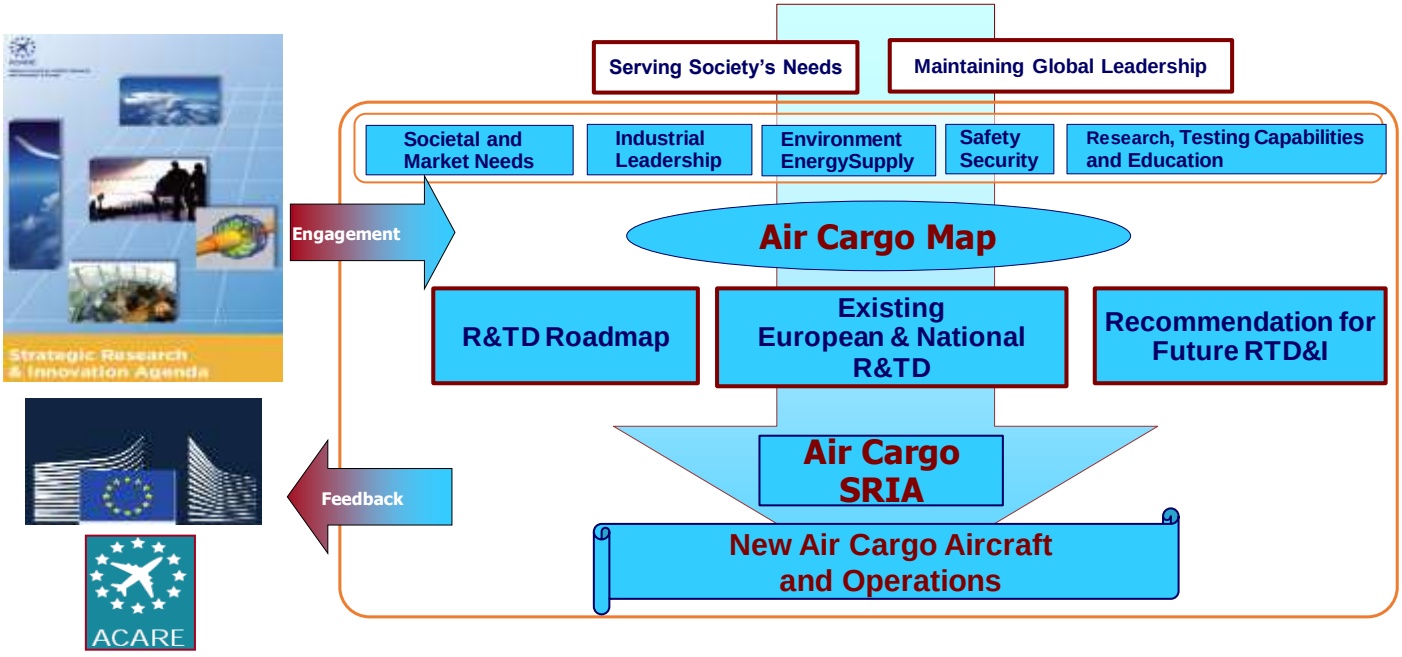
10 Conclusions

- The development of the future Air Cargo system should get the attention of the EC considering the importance of this transport system for the European social welfare, industrial leadership.
- The Cargo transport of the future has to become more and more intermodal reducing road congestion and improving the overall system. An optimal air cargo business model and efficient cargo aircraft adoption might reduce the environmental impact of the air cargo transport.
- An expert group should prepare as soon as possible a master plan to address relevant technologies for air cargo aircraft and Horizon 2020.
- The technologies to be developed include new configurations, VSTOL technology, autonomous pilotless flying, restructuring the business, integration of air cargo operations in European ATM, new engine and fuel concepts, morphing etc.
- Near term aircraft development and demonstration - As indicated in the CARGO Roadmap, the most urgent issue may be the development of new short haul aircraft. Clean Sky 2 provides the opportunities to demonstrate the feasibility of novel short haul cargo aircraft including VTOL aircraft designs.
- The incorporation of novel cargo operations should be addressed with more focus in the SESAR program. The use of alternative airports, the seamless travel in the European sky, low cost air traffic management etc. are issues that SESAR already deals with. The restructuring of the European airspace classification is another issue. The use of small UAS for very short/haul (e.g. local/urban transport tasks) needs a new approach both in regulation and in traffic management.
- The innovative aviation concepts and technologies could be addressed in the Collaborative aeronautics research part of Horizon 2020. Prime focus should be pilotless flying and the consequences for aircraft design. Research should also cover specific cargo related problems in terms of configurations, novel engines and aircraft control, low cost maintenance, safety issues as well as advanced configurations. New concepts for air cargo business should also be addressed.
- Advanced production methods and novel materials for future aircraft might be part of the Commission's materials and manufacturing program.
- The new container idea should be given sufficient attention. After an initial research phase this could be demonstrated during the lifetime of Horizon 2020.
- The availability of qualified staff is a concern that should be addressed as well. Here it will be insufficient to look only at university graduates. All the involved staff including pilots, maintenance technicians and commercial profiles needs attention to ensure that sufficient staffing levels will be available in future.
- It is important to support the development of new seamless transport chains. E-freight and the associated IT systems will be only one of the many aspects to consider.
- A total systems approach is needed where all relevant players in the transport chain are involved. Customer orientation, greening and cost will be prime drivers. The low load factors in transport need to be improved through clever cooperation. Intermodal transport like in passenger transport (see the EC sponsored MODAIR project) needs to be implemented.

Figure 19: EC

- In the short term looking to the first pillar of H2020 we see the need to take future air cargo into account in FET as well research infrastructures. We believe that the potential of air cargo should also be recognized in the ICT, nanotechnology, materials and manufacturing part of the second pillar. Innovation in SME's can benefit the Air Cargo market.
- Transport research in the third pillar should enable the demonstration of new cargo planes in future PPP, may be already in Clean Sky 2 for small planes, as well as specific technology described in this roadmap. Furthermore, generic technology issues as laminar flow, novel engines and systems like fly by wire and maintenance should be developed keeping in mind application to novel cargo aircraft.
- SESAR should take into account the new developments in air cargo. Up to now SESAR has been very much focused on scheduled passenger flights but it should increase the focus on air freight and medium and short delivery vehicles, and for the long term also including unmanned vehicles (e.g. long-haul, medium-haul and urban delivery).
- The innovative aviation concepts and technologies should take into account the air cargo opportunities for 2030 as displayed in the roadmap.
- Safety should take into account the idea of unmanned flight, coupled flight etc.
- In the EC transport program sufficient attention should be given to a customer centred, seamless, intermodal transport chain. It should deal with concepts, governance and appropriate E-tools and ensure the implementation. The future air cargo infrastructure will not only include regular airports but local landing sites as well. Such ideas should be incorporated in future research.
- Air Cargo stakeholders should be well represented in ACARE to include the air cargo needs.

- Although the smart, green and integrated transport part of the third pillar will be the focus area for research and demonstration for aviation, including air cargo, there is a need for attention in the security part as more cloud computing, data links and E-Systems need to be well protected. The recent experience in the harbour of Antwerp where a container was stolen through hacking of the information systems is just one example.
- The aviation fuel, including the full life cycle, needs attention in the energy program which is part of the third pillar but considering specific solution for aviation and air cargo.



- An optimal air cargo business approach and efficient cargo aircraft might reduce the environmental impact of European cargo transport.
- It is important to support the development of new seamless transport chains. The Cargo transport of the future has to become more and more intermodal reducing road congestion and improving the overall system.
    - **E-freight** and the associated IT systems will be only one of the many aspects to consider.
    - A **total systems approach** is needed where all relevant players in the transport chain are involved.
    - **Competitiveness, customer orientation, greening and cost** will be prime drivers. The low load factors in transport need to be improved through clever cooperation.
- For a Smart, Green and Integrated Air Cargo industry specific air cargo aircraft, technological solutions, concepts and operations are needed.
- For long haul cargo promising solutions are: Blended Wing Body (100 tons) , Formation and coupled flight.
- For medium haul cargo promising solutions are: Advanced VTOL (20 tons), Medium Airlifter (50 tons), Small Aircraft (10 tons), Very Small Aircraft (4 tons).

- For short haul cargo promising solutions are: include in the business small packages and parcels delivery (remote locations, cities).
- High priority areas for Technologies and Operations:
    - Air cargo freight containers for inter-modality.
    - Innovative VTOL vehicles with low emissions, noise and costs.
    - Safety and regulation for innovative vehicles and operations.
    - Improve Security for Time and Cost efficiency.
    - Use of smaller airports.
    - Noise shielding for night operation.
    - Insertion of new Air Cargo operations in SESAR.
    - Single pilot operations, or in the long term unmanned operations.

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