Module -1

AIR TRANSPORT SYSTEMS – INRODUCTION

1.1 Environment, Transport and Mobility

1.1.1 Environment

- Transport defines all activities, which allow movement of people or goods from one location to another.
- There are various modes of transport like road, rail, water and air. But also pipelines, cables and space transport can be considered for special purposes.
- A transport system is built on infrastructure, vehicles and operational procedures. Transport and travel are elementary drivers to develop civilization bringing people together and exchanging goods.

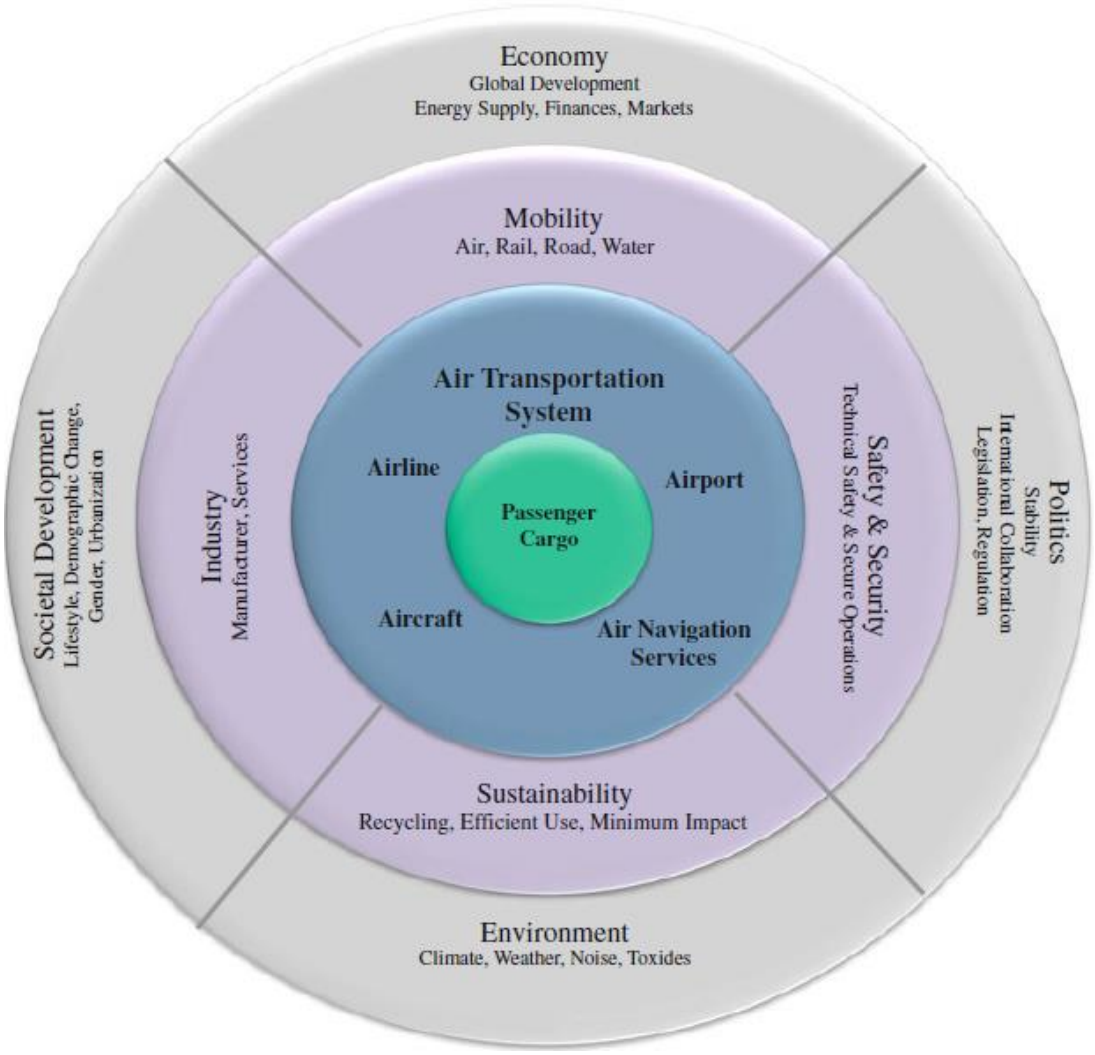


Fig: The air transport system and its environment

- As the air transport system is one of the major pillars of modern transport, above figure provides a first insight into this complex system.
- Since air transport is intended to move passengers and cargo, these elements are placed into the center of the system.
- Aircraft like fixed wing transport aircraft, rotorcraft, unmanned systems, etc. developed and produced by the manufacturers are the vehicle platforms for air transport.
- Aircraft are operated by airlines, which provide air transport as a service product. In order to enable this service product safe and efficient Air Traffic Management (ATM) performed by Air Navigation Services (ANS) has to ensure safe and scheduled aircraft flow around the world.
- Airports are understood as the interface between land and air transport, which provide the infrastructure for this interface.
- Beside these main stakeholders in civil air transport, travel agencies, ground services or maintenance, as well as military and general aviation are further operators in the sky.
- All aircraft operations, civil as well as military and general aviation are mainly influenced by society's expectations and developments.
- Politics in general, represented by authorities develops and sets the legal and regulatory framework to enable air transport.
- Economy, as a key for people's prosperity and welfare influences air transport. Other transport systems like rail, ship or automotive are operated complementary in multi-modal operations with air transport, but they are also competing.
- At last, environmental responsibility mainly in terms of climate and noise impact has become a major influence on air transport today.

1.1.2 Transport and Mobility

- Mobility itself is the people's ability to move from one location to another. It can be performed by different transportation systems and measures.
- People can move individually or in groups either by walking or for example taking bikes, cars or aircraft.
- With the development of technical features people were able to travel longer distances and reach locations much quicker.

- A fixed amount of people as well as cargo can be transported, either by a large number of transport vehicles with limited capacity of payload or using fewer vehicles providing large storage capacity.
- In order to reach another location, people today often use different transport systems during a journey. This principle is called Multi Modal Transport (MMT). Each transport mission from door to door can be described by five phases.
- Further, if in a trip different transport systems might be used, this is known as Inter Modal Transport (IMT). It is possible to compare different multi-modal transport chains, using a Five-Phase-Model (FPM) with different main track transport vehicles in a transparent way as shown in below figure.

	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
	Departure	Transition	Main Track	Transition	Arrival
Mode		Mode Change		Mode Change	
Range [km]	0 -20	<100	>>100	<100	0-20
Speed in [km/h]	0 - 50	0 - (100)	100 - 900	0 - (100)	0 - 50
Road	City	National Road	Motorway	National Road	City
Rail	Car, Taxi, PT	Railway Station	Highspeed Train	Railway Station	Car, Taxi, PT
Air	Car, Taxi, PT	Airport	Air Transport	Airport	Car, Taxi, PT
Water	Car, Taxi, PT	Harbor	Ship Transport	Harbor	Car, Taxi, PT

PT = Public Transport (Metro, Tram, Bus, ..)

Fig: Five phases of multi-modal transport

- Aviation in this context provides the unique capabilities to be the fastest and offers the largest range performance compared to the other transport systems.
- Further, it is not limited to any continental border. Therefore, aviation can connect cities on most continents directly without being hindered by oceans or mountains.
- However, air transport requires normally a mode change before and after the air phase (phase 3), which might last between 30 min and 2 h typically. This “loss” of time is the reason why air transport is only efficient at distances longer than 500 km.
- Here the geographic situation, i.e. the density of transport networks influences the attraction of a transport system significantly.

1.2 Systematic description and current challenges

1.2.1 Current Challenges of the Air Transport System

- Mobility as a whole and air transport in particular have grown dramatically during the last decades. This development is driven by man's wish to move quicker and further away.
- Air transport as a whole has a significant economic relevance. Almost 15 million jobs globally are associated directly or indirectly with the aviation industry. 7,80,000 people are directly working in the aerospace industry, while 2 million are associated with airlines around the world.
- At the airports, about 2.7 million employees are engaged, which in summary lead to 5.5 million jobs, which are directly created by the aviation industry. These figures indicate strongly the welfare impact of aviation.
- More the countries are developing, the more people's mobility increases and the economic power grows.
- As shown in below figure, from a certain level of Gross Domestic Product (GDP) of about 25,000 no further increase of mobility is observed.
- Consequently in these regions only marginal increase in passenger movements and aircraft movements are to be expected.

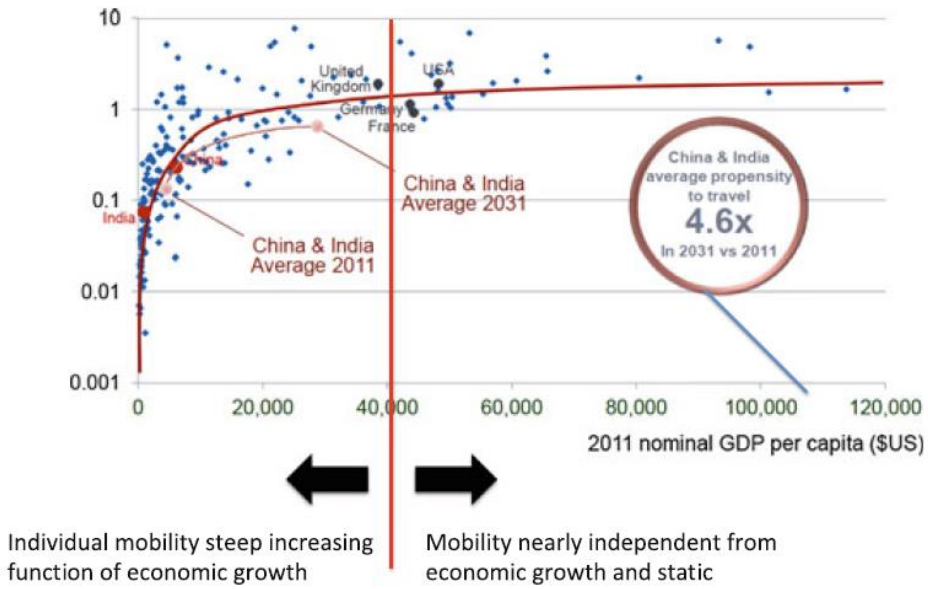


Fig: Global mobility development depending on GDP

- This growth will be heavily driven by the growing economies in Asia, especially India and China, while the highly developed countries like USA and Europe will face certain saturation in air traffic mobility.
- For those markets, the competitive situation for air transport is becoming stronger, especially since high speed trains with cruise speeds up to 400 km/h strengthened their advantage to link cities at their heart.
- Responding to these challenges in 2001, the Advisory Council of Aeronautical Research in Europe (ACARE) has defined high level targets for future improvements, to make the global air transport system competitive and attractive for the twenty-first century. These high level targets are known as the ACARE Vision 2020.
- Also in the United States targets for the future air transport have been formulated. Here on the operational field the NextGen programme especially defines objectives for more efficiency in air transport flow.
- The American N+3 project driven by NASA additionally sets requirements on improved aircraft performance.
- Comparing both approaches the European Vision 2020 can be understood as more holistic, while the American NextGen ATS addresses more technologies to increase the throughput of aircraft in the airspace and at the airport.
- These goals are set to be achieved until 2020 and refer to the ATS performance of 2000 as the reference.
- While the environmental goals concerning CO_2 and NO_x emissions are achievable by more than 50 %, an extension of the airport and airspace capacity as well as the improvement of punctuality are hard to reach until 2020.
- Further, actual research on climate impact of aviation has raised the question whether the percentage requirements on reduction of emissions are the right one, because the impact on global warming in terms of contribution to ΔT seems to be more appropriate.
- Following the ACARE vision, a new European revision on the future goals has been developed in Flightpath 2050.
- It is therefore mandatory to understand the air transport system and its complexity as a whole and to
    - analyse and identify weaknesses in the entire system as well as on substructure and subsystem level

- develop future integrated concepts as proposals for new solutions rather than single technology solutions
- improve air transport processes on global chain level and also on subsystem level.

1.2.2 A Systematic Description of Air Transport

- There are different approaches to define and structure the air transport system.
- One proposed by Wensveen is driven by a management view. Wensveen uses an economical view to address the organizational elements of air transport like regulators and associations.
- But he also addresses the different markets and economical influences. Further on, he describes the air transport system from airline perspective and its different business models.
- Mensen provides a more organizational vision on the air transport system, focusing very much on the ATM/control and the regulatory organizations. From his point of view, all institutions and procedures, which contribute to run the ATS define it.
- To approach such a complex system, Systems Engineering (SE) is an appropriate method to define and structure the various elements. A system generally consists of elements, which are related to each other (below figure). Major characteristics of a system are its boundaries, which separate a system from its environment or other systems.

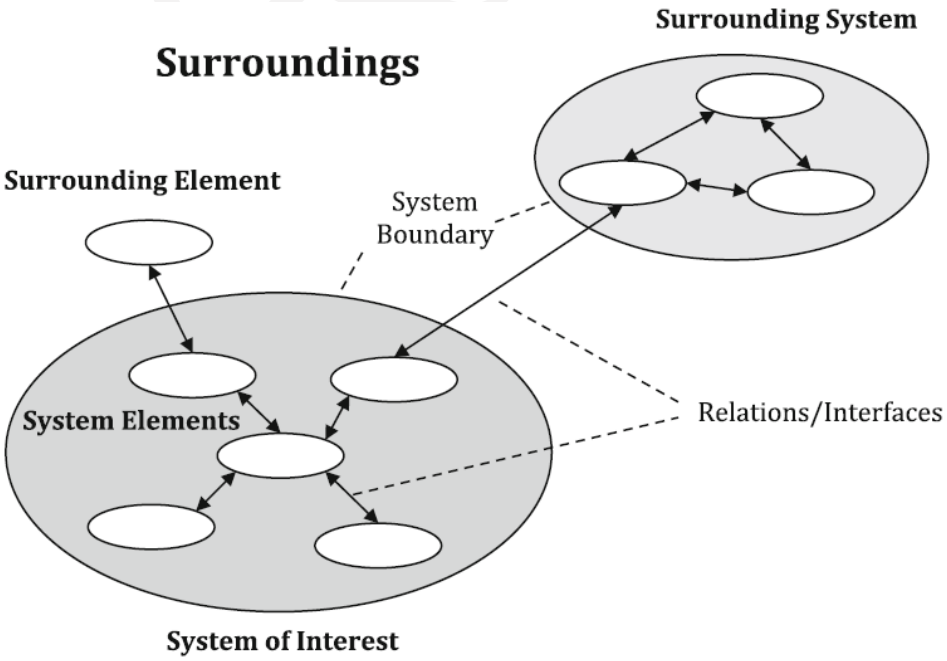


Fig: Principle of system definition

- This approach simplifies the analysis and design. A system itself can also contain various substructures, which commonly affect the higher system level.
- The air transport system is understood as a system of systems, which covers for example the aircraft, the airport and ATM as substructures. Following the system engineering philosophy, the air transport system is hierarchically structured into the system, substructures, subsystems and components:
    - the overall air transport system as the system is composed of
    - aircraft, airlines, air traffic infrastructures, airports as substructures, while
    - e.g. wing, avionics, etc. of an aircraft, or e.g. surveillance radar, air space structures of the air traffic infrastructure, or the terminal, the APRON of the airport are subsystems of one substructure and
    - e.g. flaps and slats are components of the flight control subsystem of the aircraft, while antennas and receivers are parts of the radar subsystem of ATM, check-in areas, gates are components of the airport terminal subsystem, etc.
- Generally every stakeholder in the ATS (aircraft manufacturer, airline military and general aviation) provides some infrastructures and holds some processes to make the system run.
- There might be further stakeholders, e.g. like ground service provider, meteorological services, travelling agencies, research organizations.

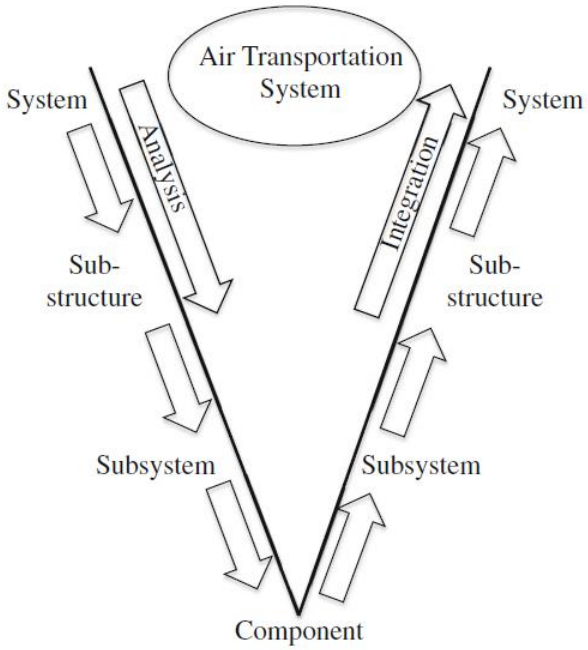


Fig: V-Model for analysis and integration of the air transport system

- The development of new solutions for the ATS follows the roadmap of a V-model like it is well known from software systems development, e.g. Mil-Std 2197, IEEE 1220 (above figure).
- Integration of technologies in the aforementioned way can be done in different ways to create systems:
    - intellectual or descriptive integration, merging physical principles and/or procedures to processes in a theoretical, functional way;
    - IT-based integration, where different models for calculation and simulation are put together in order to set up a virtual system, which allows calculation, layout and simulation;
    - physical integration, where the real hardware, operational software and procedures are put together to setup the real system;

1.3 Development of aircraft design driver-speed and range

- Any kind of modification of the various air transport systems is intended to improve the entire system leading to more efficiency.
- In this context, it is necessary to discuss efficiency and effectiveness. A popular distinction between these two performances, describes efficiency as doing things right, while effectiveness is understood as doing the right things.
- In the context of air transport this definition means, that for example the manual assembly of an aircraft is less effective than the assembly using automation, which allows much quicker and higher quality assembly.
- On the other hand, efficient air transport can be seen as the movement of passengers with as less fuel and time as possible.
- As a basis for these considerations air transport work (ATW) is defined as the amount of passenger or goods being carried over a given distance, i.e.:

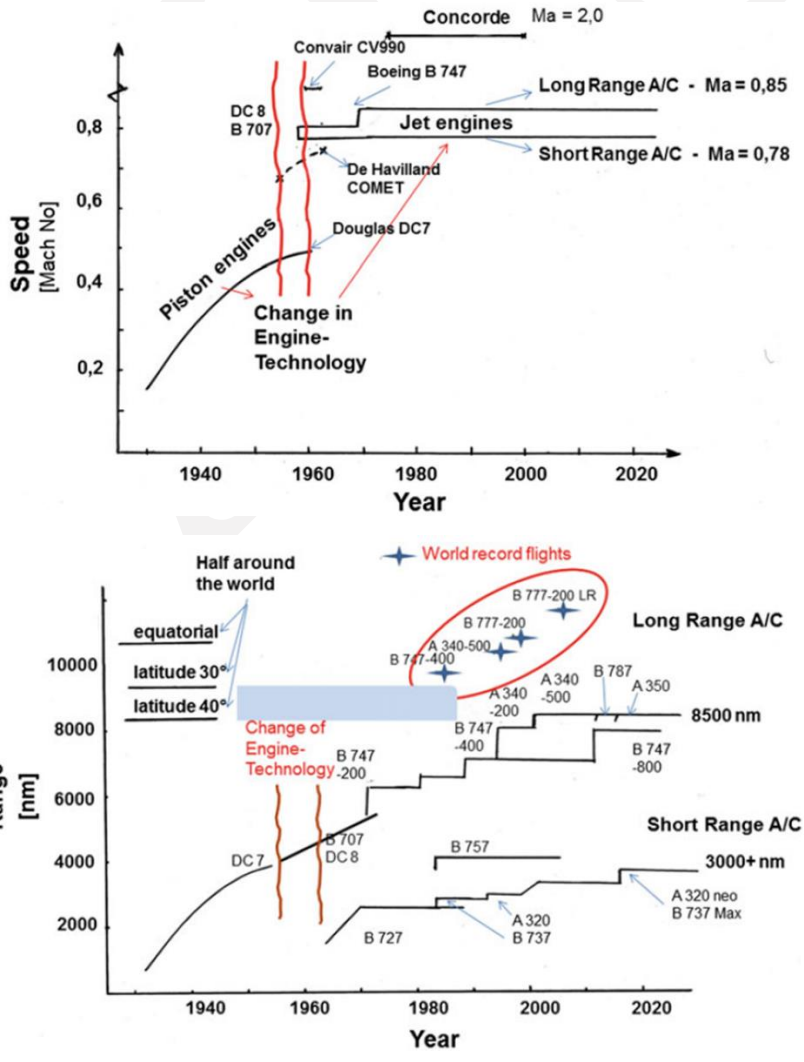
  ATW = pax or goods * distance [Pkm] or [tkm]

- Eurocontrol, in 2006 first published an approach to describe efficiency and effectiveness in air transport. Here, Key Performance Areas (KPA) and Key Performance Indicator (KPI) have been defined to describe and quantify the performance of air traffic, especially. Key
- Performance Areas in this context have been defined, like
    - Capacity and delays
    - Cost effectiveness

- Environment
- Airports

- These KPA are extended to those agreed by the 11th ICAO conference adding:
  - Access and Equity
  - Global interoperability
  - Predictability
  - Security

- To determine these KPAs, it is not sufficient to use one parameter each only. This is the reason why different KPIs have been defined to characterize the KPA. Moreover, each KPI needs to be defined in particular for its individual environment of application.
- Aircraft efficiency can be defined in two ways. First, the design efficiency in terms of the maximum payload capacity related to the operating empty mass can be used to characterize the efficiency of the design. Second, the fuel burn is a further economic characteristic of the aircraft.



- At last, environmental performance of aircraft is characterised by the amount of emissions and the noise carpet developing during take-off, cruise and landing.
- At this point, one may wonder about the missing physical aircraft performance in terms of range and speed.
- These parameters seem to be not really useful for performance indication, since their value is depending on the individual real mission.
- Cruise speed and range itself provide the capabilities of an aircraft for flexible operations on various missions.
- For airlines, those performance areas may address the fleet's wide amount of emissions as an emission indicator as well as the relation of the amount of aircraft to the annual flown kilometres, which indicates the efficiency of the operated fleet.
- The amount of accidents and incidents related to an airline fleet and flown kilometres will indicate the level of airline safety.
- At last it has to be noted, that airport specific performance indicators are still addressed within the ATM performance areas.

1.4 Development of Airports, Airlines, ICAO, Regulatory Frame work and Market Aspects

1.4.1 Development of Airports

- The development of airports followed the need, that some operators wanted to offer transport services between two points and therefore needed the necessary infrastructure.
- This started with a green plane field, some hangars or light buildings to prepare the formalities for the flight. Most of these fields had not a dedicated runway, but provided a large round circle field, where aircraft could start and land in whatever was the preferred direction related to the wind conditions at the airfield.
- Paved areas were created first at those positions, where the passengers were embarking and disembarking. Later on paved runways were installed to allow landings and takeoffs in nearly all weather conditions and during day and night.
- The title of "world's oldest airport" is disputed, but College Park Airport in Maryland, US, established in 1909 by Wilbur Wright, is generally agreed to be the world's oldest continually operating airfield, although it serves today only general aviation traffic.

- Increased aircraft traffic during World War I led to the construction of several new landing fields. Aircraft had to approach these from certain directions and this led to the development of aids for directing the approach and landing slope.
- Following the war, some of these military airfields added civil facilities for handling passenger traffic. One of the earliest such fields was Paris—Le Bourget Airport in France.
- The airports of this era used a paved "apron", which permitted night flying as well as landing heavier aircraft.
- The first lighting used on an airport started during the latter part of the 1920s; in the 1930s approach lighting came into use. These indicated the proper direction and angle of descent. The colors and flash intervals of these lights became standardized under the International Civil Aviation Organization (ICAO).
- In the 1940s, the slope-line approach system was introduced. This consisted of two rows of lights that formed a funnel indicating an aircraft's position on the glideslope. Additional lights indicated incorrect altitude and direction.
- Following World War II, airport design became more sophisticated. Passenger buildings were being grouped together in a central unit, with runways arranged in groups around the terminal and taxiways to connect the runway and the terminal area.
- Airport construction boomed during the 1960s with the introduction of jet aircraft traffic. Runways had to be extended out to 3000 m (9800 ft). The fields were constructed out of reinforced concrete using a slip-form machine that produces a continual slab with no disruptions along the length.
- The early 1960s also saw the introduction of jet bridge systems to modern airport terminals, an innovation which eliminated outdoor passenger boarding.

1.4.2 Development of Airlines

- At the beginning of air transport, the airship was used for civil transport operation.
- The first company, who started with regular air transport was DELAG (Deutsche Luftschiffahrts-Aktiengesellschaft). It was founded in 1909 with government assistance, and operated airships, manufactured by the Zeppelin Corporation. Its headquarters were in Frankfurt. The idea was to establish regular air transport between major cities in Germany.

- In 1914 - before the beginning of the 1st World War - DELAG operated seven airships on roughly *1500 routes with a total range of 175.000 km and transported 18.500 passengers without major fatalities.
- Transportation of Mail stands at the beginning of the fixed wing commercial aircraft operation.
- In the US the Post-office started the first regular post transport between Philadelphia and New York.
- Also in Europe transport of mail started the commercial operation after WW 1.
- In 1920, the first transcontinental airmail service began and the first night flights started a year later.
- However, accident rates were still high and normal passengers did not yet rely on and believe in air transport.
- The four oldest airlines that still exist but using fixed wing aircraft are Netherlands' KLM, Colombia's Avianca, Australia's Qantas, and the Czech Republic's Czech Airlines.
- Dutch Royal Airlines for the Netherlands and its Colonies (KLM) first flew in May 1920, while Qantas (which stands for Queensland and Northern Territory Aerial Services Limited) was founded in Queensland, Australia, in late 1920.
- The real intercontinental and international air transport started at the end of the 1930ies.
- New aircraft designs like the DC4, B307, He 111, FW 200 and Ju 90 had increased considerably their speed and range capability, making air transport more attractive for the passenger and the airlines.
- World War II stopped a lot of these civil transport developments as all engineering skills went into military aircraft design.
- At the end of the sixties, the aircraft Boeing B-707, Douglas DC-8, Sud Aviation-Caravelle, Tupolev Tu-104, appeared on the market and established the dominance of jet aircraft in short and long range flights and the newly established national airlines were interested to buy and operate them and develop their international network.
- Typical development of a classical "flag carrier" or national airline is started by KLM, starting in 1919.
- Common elements are to use national aircraft design (Fokker), national pilots and start to connect with the own empire (colonies, when still existing).

- Here the air transport gave a new dimension to better connect these colonies with the homeland.

1.4.3 Regulatory frame work for air transport

- Short after the First World War, when aviation became more and more relevant for commercial transportation, the "Convention of Warszawa" was signed in 1929 initially by 23 nations (in 2011 more than 130 nations) to harmonize and globalize the rules of liability.
- Two major issues were addressed, i.e.
  - A standardized and common look at the transportation documents and
  - A liable framework for air transport provider.
- To declare air transport as "international" in terms of this convention, transport must be performed between at least two countries, which signed the convention. Transport itself under these conditions is defined by
  - the origin or departure location of the transport,
  - the final destination,
  - potential intermediate stops,
  - contracting parties, i.e. the countries, the airline, the passenger.
- The characteristics named on the transportation documents are typically
  - the flight ticket for passenger transport,
  - the passenger baggage tag,
  - the airway bill.
- Referring to the "Convention of Warszawa" the air transport provider is liable for
  - personnel damages by injury, damaged health or death of travelers,
  - material damages by loss, destruction or damage of baggage or cargo,
  - inconvenience and damages by delay by exceeding time limits for passenger and goods.
- Based on these principles civil air transportation liability is established. However, damages on the ground have not yet been considered. This issue will become relevant for upcoming unmanned air vehicles, which are controlled from the ground and which have to be integrated into the air space.
- There are numerous international organizations representing the interests of the different stakeholders globally and also regionally.
  - International Civil Aviation Organization (ICAO)

- International Air Transport Association (IATA)
- Airport Council International (ACI)
- International Federations of Air Traffic Controllers (IFATCA) or Airline Pilots (IFALPA)

- Based on the "Atlantic Charta", where the nations announced in 1941 the "Freedom of the Seas", in 1944 the nations agreed upon the "Freedom of the Air", leading to the following rules:
  - Right to cross a state airspace without landing (i.e. B to C over A in Fig. 4.1)
  - Right for intermediate stop for non-traffic purposes, e.g. Aircraft problems, passenger health problems, refueling, maintenance, (i.e. B–C, but intermediate stop at A needed)
  - Right to carry people or goods from the home country of the airline, e.g. A to another state, e.g. C or B "coming from home"!
  - Right to carry people or goods from a foreign state, e.g. C to the home state of the airline, e.g. A "destined to home"
  - Right to carry people and goods between foreign countries, while the origin and destination of a flight is in the home state of the airline, e.g. flight from B to A and follow on flight from A to C or the other way round. "coming from and destined to = distribute"

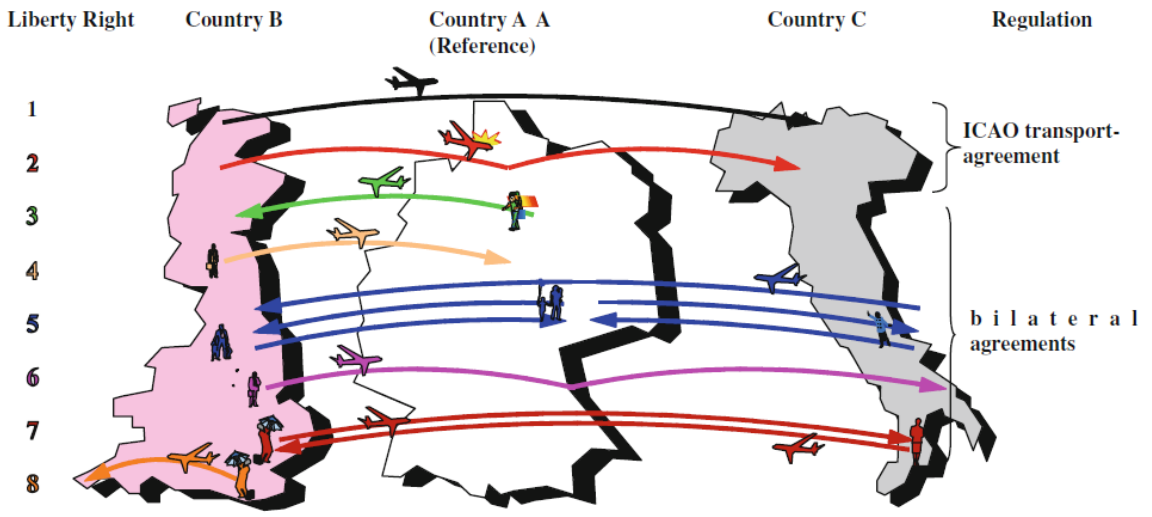


Fig. 4.1 The eight rights of freedom of the air

In the agreement at Chicago the states committed to the first five freedom rights. However, the USA withdrew from this agreement in 1946, so that the binding character was lost, although the first two freedom rights are commonly accepted.

1.4.4 The International Civil Aviation Organization—ICAO

- Due to the global character of aviation, based on the 1944 contract of Chicago about the "international civil aviation", the International Civil Aviation Organization (ICAO) was founded and located in Montreal.
- Most of the states of the world have signed the contract and are committed to develop common recommendations and regulations to enable a harmonized and consistent air transport system.
- The mission of ICAO - an intergovernmental organization - is the systematic, organized and safe development of international civil air transportation.
- Further, ICAO supports the development and operation of civil aircraft. Also, the evolution of air roads, airports and air navigation service systems is one part of the ICAO mission in order to improve continuously air transport safety and efficiency.
- As a governmental organization, ICAO looks at balanced cooperation among the member states.
- The general assembly meeting of all member states every 3 years is the ultimate decisive institution of ICAO.
- Various technical committees are installed and are responsible for the elaboration of new regulations, technical requirements and procedures in the form of standards.
- These recommendations normally called Standards and Recommended Practices (SARP) are becoming obliging when the individual state has transferred them to national law.

Table 4.1 List of SARP associated to the ICAO contract, [1]

Annex	Contents
Annex 1	Personnel licensing
Annex 2	Rules of the air
Annex 3	Meteorological service for international air navigation
Annex 4	Aeronautical charts
Annex 5	Units of measurement to be used in air and ground operations
Annex 6	Operation of aircraft—international commercial air transport—aeroplanes, general aviation—aeroplanes, helicopters (part I–III)
Annex 7	Aircraft nationality and registration marks
Annex 8	Airworthiness of aircraft
Annex 9	Facilitation
Annex 10	Aeronautical telecommunications—(surveillance radar and collision avoidance systems)—(volume I–V)
Annex 11	Air traffic services
Annex 12	Search and rescue
Annex 13	Aircraft accident and incident investigation
Annex 14	Aerodromes—aerodrome design and operations, heliports (volume I–II)
Annex 15	Aeronautical Information Services
Annex 16	Environmental protection—aircraft engine emissions and aircraft noise (volume I–II)
Annex 17	Security
Annex 18	The safe transport of dangerous goods by air

1.4.5 National and European Regulatory Organizations

- The international regulations need to be transferred to national law and subsequent orders to become operational since air law is under national authority.
- To ensure the maximum level of safety of aviation in Europe as well as in the United States, so-called "safety authorities" have been established in the past to ensure the sovereign responsibility of the various countries for safe aviation.
- The Federal Aviation Administration (FAA) was founded in the United States in 1903, i.e. in the year of the worldwide first engine driven flight of the Wright brothers.
- FAA is in charge of all regulations, processes and requirements to ensure safety of aircraft, airports and air traffic management.
- Over the decades in Europe each nation had its own aviation safety agency, since air safety is a sovereign responsibility within the country borders.
- For example, in Germany the Federal Aviation Office, called "Luftfahrt-Bundesamt", was in charge of all aspects of aviation safety.
- In 2002, the EU member states founded the European Aviation Safety Authority (EASA) merging and transferring their national responsibility on a European level.
- The EASA is the more powerful successor of the European Joint Aviation Authority (JAA), which was established in 1970.
- EASA is the European certification authority and shall promote the development of common standards in all relevant fields of civil aviation safety and also environment in Europe.
- Worldwide, there are still some specific national regulations in place, but most countries have adopted the FAA and JAA regulations as national standard.
- Although not mentioned here, the structure and philosophy of aviation safety, e.g. in Canada (Canadian Aviation Administration, CAA), Great Britain (Civil Aviation Authority, CAA) and France (Direction General l'Aviation Civil, DGAC) is very similar.

1.4.6 The International Air Transport Association

- While the ICAO represents the world states community in aviation, the International Air Transport Association (IATA) is the federation of the aviation industry, especially the airlines of the world.

- Originally founded by the national flag carriers, which were mainly owned by the hosting countries, today about 240 airlines are members of IATA. These represent approximately 93 % of all worldwide international airlines.
- IATA defines its mission by supporting safe, regular and economical civil air transportation worldwide, which sounds similar to the ICAO mission.
- Additionally, it is pushing for the collaboration of all companies involved in aviation, by coordinating the development of common technical and economical methods.

1.4.7 Market aspects

- The aviation and space have become after WWII a very dominant area for all big countries, especially for the four allied countries, the winner of this war.
- During the cold war (between 1948 and 1990) military and space developments were in the focus of the two dominating blocks, the Western NATO block with the United States of America and its European Allies on one side and the Eastern block with the Soviet Union and its allies on the other side.
- Big military budgets were available allowing the development of continuously novel aeronautical and space vehicles.
- Focus may have been strictly on military usage, but technologies to improve the thrust to weight ratio for military aircraft could also be directly applied to civil aircraft vehicles and the big aeronautical industry in the USA with Boeing, Lockheed, Douglas, Mc Donnell.
- Starting from the 1960s till the 1980s (1955–1980) the American civil aircraft manufacturers were dominating the worldwide civil aircraft market.
- The Boeing Company had successfully designed the B707 aircraft and by using the same fuselage cross-section for the development of their short and medium range aircraft, the B727, B-737 and B757, Boeing developed a complete aircraft family with 2- 3- and 4 engines by always using the same fuselage cross-section.
- Boeing was suddenly confronted with a big crisis, as all their investment for producing the B747 was challenged and the airline was no longer able and willing to buy this proposed big “Jumbo-aircraft”.
- The Concorde consortium with the French “Aerospatiale” company and the British “British Aerospace” company had developed their civil supersonic transport concept called “Concorde”, a 100-seater aircraft, which could fly.

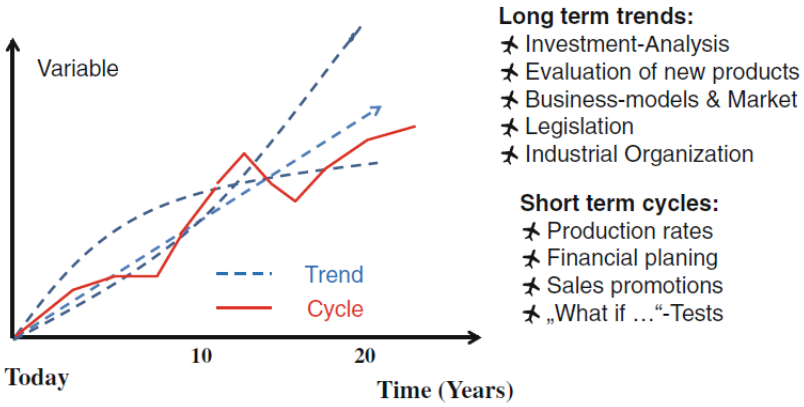
- The Concorde consortium had already received orders for about 100 aircraft, when the oil crisis started in 1973. supersonically (Mach 2).
- This commercial disaster of European Concorde was in line with some other European subsonic aircraft programmes.
- Other designs like Mercure from Dassault and the German attempt of a 40 seater named VW 614 also failed to fulfil the market needs.
- The European efforts on civil aircraft were regrouped in 1968 in a new consortium, integrating the French industry Aerospatiale, the German industry under "Deutsche Airbus" and the British industry of Hawker Siddley.
- This consortium was named Airbus and developed a new design for a twin engine wide body configuration, named Airbus A-300.
- In 1974, the first aircraft was delivered to AirFrance, but the market acceptance was at the beginning fairly poor, as it was not very visible whether the consortium would be willing to support the aircraft over the next 20 years of operation.
- The next programmes followed in a 5-year sequence, the A310 in 1982, the A320 in 1988 and the A330/340 in 1992.

Market Forecast for new passenger and freight aircraft for next 20 years (2013 – 2032)

Category	Seat capacity	Boeing CMO Current Market Outlook	Airbus GMF Global Market Forecast
Single-Aisle Aircraft	110 - 200	24.670	20.242
Twin-Aisle Aircraft	220 - 350	7.830	7.273
Very Large Aircraft	≥ 400	760	1.711
Total Number		33.260	29.226
Market value [B$]		4.840	4.400

- Market predictions are mandatory in a long-term market like the civil aeronautical industry.
- Market prediction methods are developed by the aircraft manufacturers. They have to identify the market drivers and long-term aspects, which may influence the air transport market, including other means of transport (High-speed trains, ships, etc.) and societal changes (Mobile phone, Smartphone, Virtual travelling, etc.).
- Engine manufacturers, suppliers and research institutes are also developing their own market forecast methodology in order to get a better understanding and feeling about the future.

- All forecast methods differentiate between cycles and trends.



Difference between trend and cycle

- "Trend" is defining the long-term tendency, independent of short-term aspects, caused by political or economic perturbations. The long term trend—normally a period of 20 years.
- Cycles are determined by "Short term"—influences, perturbations from political or economic side—normally between 1 and 2 years.
- There is no unique and generally viable method. Generally two different approaches for market forecast exist:
    - Top-down approach
    - Bottom-up approach
    - In addition to these two approaches, scenario techniques are used to identify specific risks and potential benefits for future market trends.

1.4.7.1 Top – Down approach

- The method of "Top-down-approach" starts from the market development of the last 10–20 years and assumes a continuation of the long-term trend with an adaptation of some main parameters such as:
    - Global growth product
    - Yield from the airlines
    - World Economic growth:
    - RPK-development: (worldwide or per region)
    - Ticket price trend: in real terms
    - Fuel price development:
- For the top-down approach, the world will then be separated into several geographical sectors (North America, Europe, Asia-Pacific, Near East, etc.) and the

main routes and traffic flows between these regions and within these regions will be identified and analyzed.

- The top-down approach consists of the following steps:
  1) Select a region A and determine the available capacity expressed in ASK (available seat kilometres)
  2) Assume an average traffic growth factor for the next 20-year period
  3) Obtain as a result the expected traffic volume (RPK) for the year N+20
  4) Convert the RPK into ASK by an assumption about the development of the load factor
  5) Make reasonable assumptions regarding the productivity trend (block speed, seat capacity, etc.)
  6) Look at the world fleet of today (day of analysis) in terms of size and a/c category
  7) Split the world's fleet into region and age of aircraft
  8) Assumptions for retirement of ageing aircraft (retirement or conversion to freighter)
  9) Subtract the existing aircraft still flying in year N+20 from the demand in step 5
  10) Define the number of future seats required per year and region
  11) With assumption on aircraft size and route frequency, the number of aircraft to be delivered per year and region can be obtained.

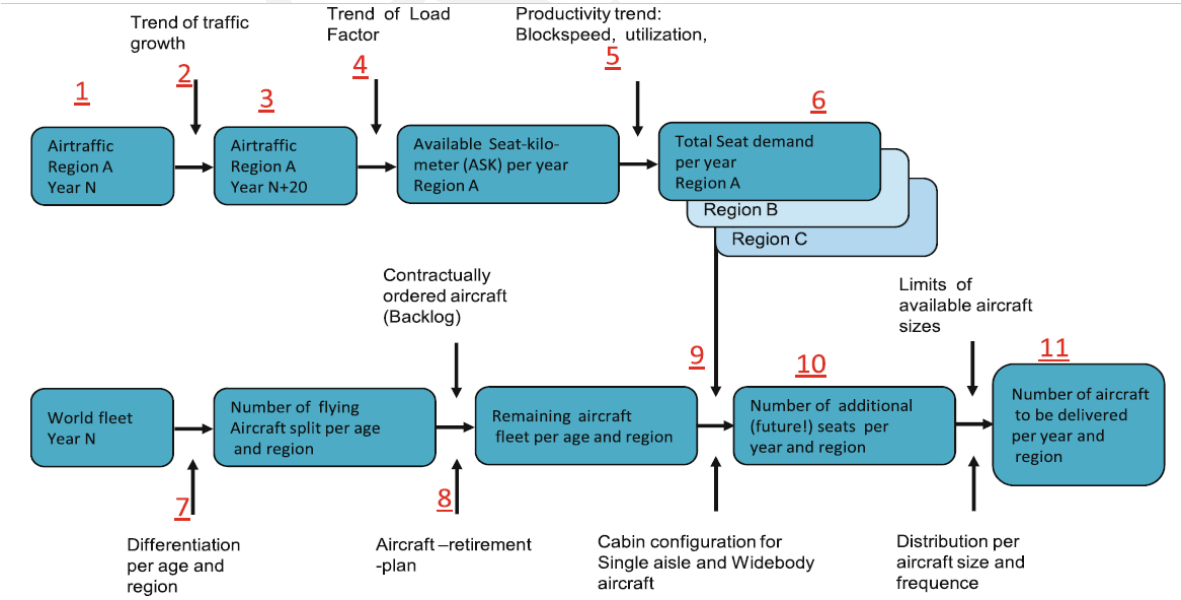


Fig: Methodology for top-down market forecast

- Some additional assumptions may also be integrated and quantified as:
  - Growth of population:
  - International trade development: (may stimulate long range and cargo traffic?)
  - Political factors:
    - low liberalization of markets,
    - environmental concerns may reduce the demand for air transport,
    - fuel taxes may increase ticket prices and reduce transport demand.
  - Competitive transport systems:

    – Telecommunication may reduce business trips and

    – high-speed trains (ICE, TGV, ..) may replace partly short range air routes.

1.4.7.2 Bottom – Up approach

- The bottom-up approach starts by analyzing individual national or regional airline situations.
- For each airline the operational aircraft fleet of today is used as basis and the airline's specific development plan is taken as basis for the forecast of aircraft requirements for the next 20 years.
- Below figure shows the methodology used for the bottom-up process:
  1) The bottom-up process starts from the actual airline situation, the actual fleet, the route network, the load factor, the aircraft retirement plan, the backlog and the financial situation of the airline.
  2) The actual flight plans of all airlines of a country/region will be taken and analysed. The flight capacity and frequency of all aircraft in operation in this region.
  3) The flight capacity and frequency of all aircraft in operation in this region by each airline have to be identified.
  4) Assumptions about the traffic growth over the next 20 years, the economic development of the region, the development of load factor and the integration of new airlines in this market have to be assumed.
  5) For this region and the airlines under investigation, all available seats per each route, per period (day, week, month, year), per airline can be listed. This defines the actual "status quo".

6) From the situation in the region, each individual airline and its fleet development over the next 20 years can be developed.
7) The addition of all airlines with their capacities and development plans have to be integrated to define the future capacity needs of this region.

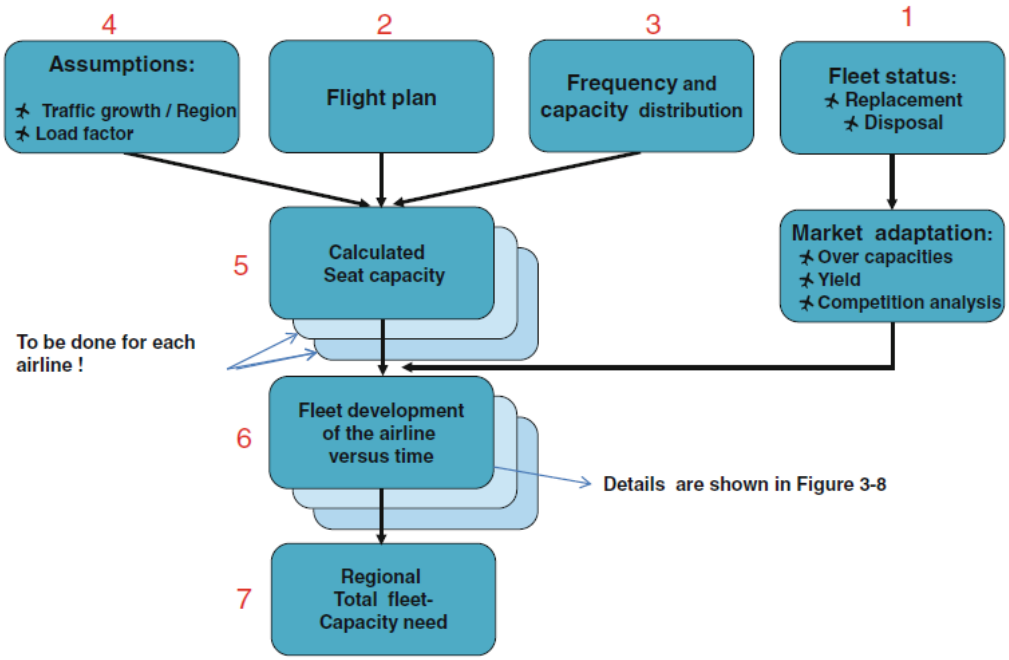


Fig: Market forecast methodology "Bottom-Up—Approach"

- The bottom-up approach is principally more precise compared to the top-down approach, but this approach is also more complex and has more risk factors included.
- The risk in the methodology is that the expansion plans of the airline are often not very realistic. Often, they overestimate their individual growth potential, because even the competitors will increase their capacities.
- The competitive situation will anyway lead to some compromises in terms of capacity growth for each individual airline and all ambitious strategic visions will have to face a realistic trend.

1.4.7.3 Scenario Techniques for Risk Assessment

- Scenario techniques are a way to analyse complex systems and their future development.
- Scenario techniques are widely used in several domains where long-term conditions have to be investigated, drivers for change to be analysed and possible future strategies to be defined.

- The great benefit of scenario techniques is the involvement and participation of different specialists from all disciplines, their input and the common discussion about the major influencing parameters, the common understanding about major drivers and the well-structured way into future possible worlds, which will have an influence on the future long-term visions.
- For the aeronautical scenarios, the main parameters are kerosene prices, alternative energies, environmental challenges, societal acceptance and hindrances for air transport, alternative transport modes, commodities of air transport, etc.
- The scenario technique is a methodology, which is using normally five steps:
  1) Focus and definition of the problem; definition of all parameters of interest and influence; definition of overall scope.
  2) In step 2 all parameters of importance for the problem have to be defined (normally 30–50 parameters, like fuel price, traffic growth, GDP growth, etc.). An impact matrix with all parameters has to be established and then possible interactions and interdependencies/reactions between all parameters have to be quantified in rough terms.
  3) Step 3 includes the identification of alternatives and a critical review of all parameters and the establishing of reasonable extremes for all chosen parameters.
  4) Based on the impact matrix, a specific tool will help to define a large quantity of future scenarios. By clustering of several solutions and a critical review of all established scenarios, 3–5 main scenarios will finally be selected and specified in more detail, amongst them: one trend scenario and several adverse and alternative scenarios.
  5) The last step is then the analysis of the selected scenarios. Using the basic parameters, it is helpful to see which parameters are the drivers for the future and which are more dependent and "driven" parameters.
- The importance for a successful scenario process is:
  - a very competent group of several specialists from different disciplines (engineering, manufacturing, marketing, financial, human resources, communication etc.),
  - the support from the top management and
  - finally, a professional moderator to control and manage the scenario process.