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The Aviation Industry as Mode of Transportation

Bharpur S. Abhi[1] and Ashish N. Noel[2]

[1]Airlines and Tourism, University Institute of Tourism and Hospitality Management, Chandigarh University
[2]Hotel and Hospitality Management, University Institute of Tourism and Hospitality Management, Chandigarh University
E-mail: [1]smartabhi87@gmail.com, [2]ashnoel2003@gmail.com

Abstract—*This paper discusses the development of the aviation sector, as a branch of public transport mode and systems, and highlights the "systems characteristics" of the industry. The paper begins with a brief of early historical events that opened up as the way to the establishment of the airline industry at the global level, as we know it today. Focus was given to the deregulation process that took place in the 1970s, since it was the major event that altered completely the way in which the industry operated. With deregulation, the airlines industry became physically structured as a wide network, and a systems thinking view became the prevailing tool to model and talk about commercial aviation. It also analyzes some sub-systems of the industry, namely the aircrafts and the ATC (Air Traffic Control), and discusses its relationship to other industries and to the environment at the international level.*

1. HISTORICAL EVENTS (1900-1970)

Using the skies has been a dream for men ever since, but it was just in the beginning of the 20th century that some experiments were successfully conducted. The first interesting records date from 1903, when Orville and Wilbur Wright (later known as the Wright brothers) took the first powered flight in a heavier-than-air machine. Before, people had just flown balloons and gliders. This was a 120-foot 12-second flight in North Carolina. Eleven years later, the first scheduled air service began in Florida. This was a plane, designed by Glenn Curtiss, which took one passenger at a time across Tampa Bay. The trip was 18 miles long and took about 23 minutes, for a price of $5.

In the years after WWI, a new and important source of demand for aircrafts came from airmail. In 1917, the Congress appropriated $100000 for an experimental airmail service to be conducted jointly by the Army and the Post Office between New York City and Washington DC. However, by that time, planes could not flight at night and mail had to be handed off to trains by the end of the day. The next important development was the installation of beacons, allowing pilots to do night flights. The first beacon system was deployed in Ohio with beacons visible in 10-seconds intervals.

Also in 1995, President Calvin Collidge appointed the Morrow board (named after its chairman Dwight Morrow, a senior partner at J.P. Morgan) to recommend a national aviation policy. This board concluded that the government should set specific standards for civil aviation outside the military. These standards were accepted immediately and put into practice by the Air Commerce Act of 1926, by which the government stipulated that airmail should be paid according to weight, which simplified payments significantly.

In 1927, two key events altered the history of aviation. First, Henry Ford designed the first duralumin aircraft, the Tim Goose. This was the first aircraft designed primarily to carry passengers. The Tim Goose also had the Ford Trmotor, which allowed it to travel at speeds of 130 mph. Second, Charles Lindberg completed the first non-stop flight across the Atlantic Ocean. He flew from NYC to Paris in about 33 hours with the Spirit of St. Louis, a 28-feet long plane with a wing-span of 46 feet.

During the 1950s and 1960s, the Cold War fueled funding to develop jets and transfer technology to the commercial sector. An example is the Boeing 707, with was adapted from the KC-135, a jet tanker. Other innovations from these decades include swept-back wings and the use of Kerosene.

However, also during these two decades, many accidents happened with airplanes. In 1956, two airplanes collided above Grand Canyon, killing 128 people. The airspace was getting too crowded and Congress passed in 1958 the Federal Aviation Act.

2. THE INDUSTRY AS A SYSTEM AND THE PROCESS OF DEREGULATION

The history of the airline industry until the 1970s is pretty much related to improving aircrafts and flight conditions. In the first half of the 20th century, this was done with a military focus, because demand for aircrafts came mostly from World War I and World War II. It was only in the second half of the century that innovations started to spill over to the commercial side and planes to carry passengers started being designed. By the end of the 1970s, aircraft technology seemed finally to mature and people worldwide started looking for air transportation services.

People started looking at the airline industry as a system and a sub-system of the larger economy in the early 1970s. The oil embargo of 1973 made fuel prices to skyrocket and people in the industry felt strongly, and for the very first time, that

airlines interconnect to other industries and receive **inputs** from them, such as fuel. Also in the 1970s, and with the establishment of mature flight technology, people started talking about the **purpose** of the airline industry, which is related to transport people. The industry started being seen as a system of **interdependent** airlines that needed specific policy tools and actions for **development**, **design** and **management**.

Other innovations following the deregulation of the industry include frequent flyer programs, computer reservation systems and code-sharing flights. However, more importantly than all these innovations, deregulation shifted focus to **competition and interaction** among airlines, bringing a **systems thinking paradigm** to the airline sector. The 1970s was the clearest turning point to a systems approach to the airline industry.

3. STRUCTURE OF THE INDUSTRY AND OF AN AIRLINE

The structure of the airline industry presents many aspects of a system and also many characteristics of a complex system. Part of the work developed by the DOT and the FAA is concerned with defining the major **element** of the industry: the airline. Airline must be certified by the DOT, which issues a "fitness" certificate (issued when financing and management are in place to provide scheduled service) and by the FAA, which issues a "operation" certificate (issued when a list of 121 requirements are satisfied).

Within the industry, an airline is itself a system. Its organic picture reflects the combination of **functions assembled together to produce a final and unique output**.

In the picture, Line Personnel includes every person related to operating a flight, that is, mechanics, pilots, reservation clerks, airport and gate personnel, ramp-service agents and security guards. Note that this chart includes sub-contracting. Typical sub-contracted services include cleaning, fueling, security, food and maintenance. Explicitly introducing and considering sub-contracting acknowledges the existence of a system **surrounding** the airline industry and inter-industry **interactions**. In other words, the airline is put into a **context**, a web of interacting industries. Consequently, it may be less expensive to acquire services from other industries than having people able to perform every single task.

4. ECONOMICS OF AN AIRLINE

The airline industry is a very particular system. Airlines provide a service, which is to transport a passenger between two cities at an agreed price. There is no physical product given to the consumer, nor inventory created and stored. Airlines also exhibit very particular economics that, over time, have motivated specific **management** concepts, tools and practices. Some of them are analyzed in this section..

Airlines' revenues come primarily from passengers (75% passengers, 15% cargo shippers). Most of the revenue associates with passengers (around 80%) come from domestic travel. Travel agencies, with computer-based reservation systems, are paramount in ticket sales. They account for 80% of the tickets issued. Note that travel agencies are elements outside the airline itself that have a huge impact on the economics of the system. Therefore, when drawing the **boundary** of the airline industry, one has to take them into account.

The management tools employed in the industry include general principles applied to very particular concepts of an airline. For example, a very useful indicator is the **break-even load factor**, which in the context of this industry means the percentage of seats that an airline has to sell to cover its costs. This is usually around 66%. Airlines operate near this margin and 1 or 2 seats in a flight can make the difference between profit and loss.

5. ENGINEERING AN AIRCRAFT AND A FLIGHT

This section looks at the engineering side of the industry and highlights its systems characteristics. The first example is the aircraft, which is itself a (mechanical) system. **Systems Dynamics** approaches have been largely used to improve aircraft performance and flight conditions.

Fig. 1 depicts an airplane and its sub-systems: the fuselage, the spoilers, the rudder, among others. Airplanes fly when the movement of air across their wings creates an upward force on the plane that is greater than the force of the gravity. This is known as the Bernoulli Principle, after the discoveries of Daniel Bernoulli, an 18th century Swiss mathematician who found that the pressure exerted by a moving fluid is inversely proportional to its speed.

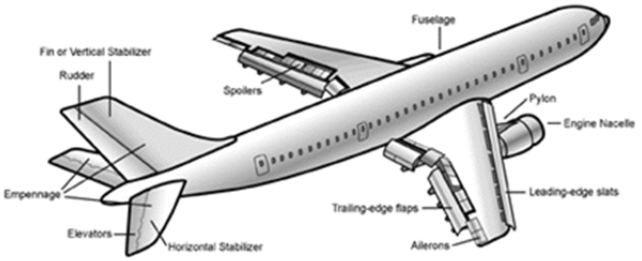

Fig. 1: Schematic representation of an airplane.

Dynamic systems **simulations** applying this principle allowed researchers to design better wings. Today, wings are flat and slanted slightly downward from front to back, so that the air moving around them has a longer way to travel over the top than it does underneath, creating a lift for the plane.

6. THE AIR TRAFFIC CONTROL AND FREE FLIGHT

The Air Traffic Control (ATC) system is responsible for managing air traffic. It is run by the FAA with a twofold

purpose: to maintain a safe separation of aircrafts flying over the US and to make aircraft traffic to move as efficiently as possible. The ATC is actually a good place in the airline industry to appreciate its **systems-like structure**. The ATC organizes all the flights in the country (therefore, implementing a **centralized** architecture for the industry) and was created based on the idea of a broad and nation-wide system of scheduled flights, which did not existed before.

A key facility in overseeing the **entire ATC system** is the FAA's Air Traffic Control System Command Center (ATCSCC), located in Herndon, VA. It looks for situations that might create bottlenecks and setups up management plans to control the traffic into and out the troubled sectors. The goal of such a plan is to keep traffic at the trouble spots manageable for the controllers. The importance of the ATCSCC becomes clear when one acknowledges that, on average, there are 900 daily flight delays of 15 minutes or more, which cost to the airlines and customers around $5 Billion USD a year.

The Free Flight concept is based on two airspace zones, protected and alert, the sizes of which are based on the aircraft's speed, performance characteristics, and communications, navigation, and surveillance equipment. The protected zone, the one closest to the aircraft, can never meet the protected zone of another aircraft. The alert zone extends well beyond the protected zone and, upon contact with another aircraft's alert zone, a pilot or air traffic controller will determine if a course correction is required. In principle, until the alert zones touch, aircraft can maneuver freely.

7. ACCIDENTS AND SAFETY

Safety is a major topic in the airline industry, particularly after the events of September 11th and the recent plane crash in Queens, NY. Accidents are investigated by the National Transportation Safety Board (NTSB). The records show that, in 1999, there was an average of 0.3 (2 in 1978) fatal accidents per 1 billion miles flown. Also, in a typical three-month period, more people die on the nation's highways than have died in all airline accidents since the advent of commercial aviation.

8. RELATIONSHIP TO THE ENVIRONMENT

This section discusses briefly the relationship between the airline industry and the environment. The major point is that factoring environmental concerns into the industry is a way to acknowledge a **boundary** between the airline industry and the larger society and to take into account the 2-way interactions that occur across that boundary. Actually, most of the work in this field has been looking at setting standards for those interactions, such as limiting plane emissions of gases and limiting the levels of noise.

9. RELATED UNIVERSITY-BASED R&D

This section is devoted to analyzing the path of academic research in fields related to the airline industry. It includes a brief analysis of what has been done at MIT, which is clearly a good place to look at for this type of information, given its strong links to the industry both during war-time and the Cold War period.

MIT started a Laboratory of Aeronautical Engineering in 1913 and founded the Department of Aeronautical Engineering in 1939, one year after the Civil Aeronautics Act. This department changed name to Department of Aeronautics and Astronautics in 1959 and, 4 years later, the Center for Space Research was created jointly by the Experimental Astronomy Laboratory, the Space Propulsion Laboratory and the Man-Vehicle Laboratory. After the early focus on military-oriented aircrafts, the 1960s shifted attention to research towards the space. This shift came along with the desire of President Nixon to "… develop an entirely new type of space transportation **system** designed to help transform the space frontier of the 1970s into familiar territory…"

Another way to understand the direction in which the department is moving is to look at recent updates in the curriculum. New courses offered include, for example, Advanced Software Engineering, Communications Systems Engineering and Space Systems Engineering (this one taught by Daniel Hastings, Director of the Technology and Policy Program at MIT). This sample shows the emphasis on systems thinking and the diversification of courses into areas that are related to aero/astro, like software and communications, but do not belong to the core knowledge fields and competencies developed in the department.

10. SYNTHESIS AND CONCLUSION

The airline industry was born from technological breakthroughs in aviation that started in the early 1900s and keep on going these days. The first half of the 20th century was like the **"incubation period"** for the industry, during which technology was developed and became mature. During that time, there was no significant notion of a system of scheduled flights and people looked mainly at improving aircrafts and flight conditions rather than managing fleets of airplanes. Most documents about the industry up to World War II refer to one-time historical flights (e.g. the Wright brothers, Charles Lindberg) and particular innovations (e.g. beacons, the radar, the jet-engine).

A major element of the airline industry is the Air Traffic Control system, which oversees air traffic over the entire US territory. Its major concerns are to maintain a safe separation of aircrafts and make air traffic to move as efficiently as possible. The ATC anticipates bottlenecks and runs management plans to alleviate the negative effects of those situations. The ATC is a **centralized** entity ran by the FAA that **oversees the entire system**. One of the major challenges

for the industry during the next decade is to turn the ATC into a **distributed** flight management system, yielding a more efficient National Air Space without decreasing the level of safety experienced today.

11. RESOURCES USED

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