Lighter-than-air v. Heavier-than-air: How can Network Effects Explain the Failure of Airship-Technology?

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Airships provided the first commercial albeit rudimentary air transportation services. The aeroplane took over this sector more and more in the course of time. This paper identifies the main reason for this development: the array of airfields and the service network for aeroplanes developed much more rapidly than that for airships. Huge rigid airships required a different network with more expensive equipment and therefore this infrastructure, along with the associated service network, grew much more slowly. Thus, airoplane networks surpassed a crucial volume of investment much earlier and displaced the airship, in spite of the fact that in civil aviation the airship possessed technological advantages.

1. Introduction

When the German rigid airship *LZ 129 Hindenburg* exploded over the U.S. Airship Base at Lakehurst, New Jersey, on 6 May 1937, the sole operating commercial airship transportation service was totally abandoned (Bauer and Duggan 1999; de Syon 2002). This accident marked the end of the commercial airship era. This development was reiterated in literature on the subject for many years but was ignored by the main protagonists in this field. Generally modern economic theory concerning the struggle between competing technologies and net effects is a useful tool with which to analyse this question. Therefore, any appreciable attempt to build a network by establishing operating bases and service routes in the United States and in Germany, and in intercontinental travel, both by airships and by aeroplanes, had to be reconstructed.

In spite of the fact that in economic theory the terms "net" and "network" are used simultaneously, in this paper we use these terms in

a different manner: the term "net" indicates physical facilities such as airports, airfields or airship-bases. Their infrastructure is, however, very different: aeroplanes need hangars, runways, aviation-fuel facilities, and aeroplane-specific repair-stations and regular maintenance facilities. Huge rigid airships, such as Zeppelins, however, required much bigger hangars in gigantic halls, mooring masts, and aviation-fuel or diesel-stations, as well as 'lifting-gas' stations, airship-specific repair-stations and maintenance facilities with totally different technical equipment and professional skills from those needed for aeroplanes. Both airships and aeroplanes required terminals and passenger facilities, as well as transport connections to railways or to the road network. This totality and the geographic distribution of airfields, airports, or airship-bases constitute a physical "net", but with the term "network" we indicate the use of this net as interlinked meeting-points or route destinations. They were served by regular services. By services we mean any transportation of passengers, airmail and, sometimes, freight. The term "network" is associated with a profitable economic interaction and requires a physical net in order to function.

The speed at which the very specific physical net, both of airships and of aeroplanes, grew will now be analysed. Furthermore it will be debated whether quality had surpassed quantity as far as airfields for airships and airports for aeroplanes are concerned. A further analysis will show how rapidly the customer-service networks of both technologies grew.

2. Theoretical Considerations: the Importance of the Growth of Physical Nets in Rival Technologies

Economic theory regarding the spread of the new technologies established that the ability to create a network for the user was a crucial factor. Creating an attractive network, using increasing returns for the facilities of a physical net was essential.

The main characteristics of a network-market are significant economies in scale of production, switching costs and lock-in effects, consumption externalities, and complementary, compatibility as well as standards (Shy

2001; Economides 1996). Economies of scale in production imply that the prototype has huge and non-recoverable costs and all further production is notably less costly (Arthur 1989). Almost every airship was a unique device, whereas aeroplanes were mass-produced after World War I. Because only a relatively small number of airships went into operation compared to thousands of aeroplanes, it was more attractive to build many more airfields and airports than airship bases. An airfield, however, requires different equipment from an airship-base: they are not compatible unless equipped for both technologies. The sum of all existing airfields defines a physical net of potential and technically-equipped destinations. Passengers determine networks: a tightly-knit net of airfields makes it easier to reach a desired destination – and more profitable for airlines or airship-lines to offer different services to their customers, e.g. more routes to travel as well as more frequent flights. Therefore, a net of airfields and airports, or airship-bases respectively, can be regarded as "hardware" and its being filled by the service-supplier and used by the customers may be regarded as "software" (Church and Gandal 1996; Gandal *et al* 2000). In our case, the routes and the transportation-service were offered by airlines or airship-lines.

All this culminated in a race between the rate of growth of the two physical nets, one usable for aeroplanes and the other for airships, but both offering commercial services to the customer wanting to travel or wanting his airmail to be transported quickly and efficiently. If one of the nets grew faster than the rival one, the network services of the slower-growing net became increasingly unattractive. Therefore, a physical net has a crucial size and the net which is the first to surpass this crucial size wins. Any investment by the "winning" network is an entry-deterrent for rival networks, which started later or grew more slowly (Dixit 1980). Then again, a switch to another net or network creates costs no one is willing to bear, even if it is technologically better or more useful (Lieberman and Montgomery 1988; Farrell and Saloner 1985). Because the speed of building a net was important, it may be assumed that whoever was first to begin building "his" net had a clear first-mover advantage over his rivals (Farrell and Saloner 1986; Katz and Shapiro 1986). The example analysed here proves the opposite because the

technology that lost the race was unable to realize significant economies of scale in production – the starting point of our theoretical considerations.

3. Short-range and Continental Commercial Transportation Networks for Airship Services

3.1 Failure to Build a Commercial Airship Network in Europe. Airship technology created working vehicles much earlier than aeroplane technology did. After the first substantial theoretical suggestions by the Frenchman Jean Baptiste Meusnier de la Place in 1784, the development of dirigibles proceeded during the nineteenth century: the first successful operating dirigibles were built by the Frenchmen Henry Giffard in 1852, the Tissandier brothers in 1883 and in 1884, Krebs and Renard in 1884, and Henry Julliot in 1897. The Germans Haenlein in 1872 and Wölfert in 1896 also built dirigibles. Their constructions were so-called blimps or keel-stabilized blimps. Plans for building large rigid airships were suggested by the Frenchman Prosper Meller in 1851 and by R. B. Boyman in Britain in 1866. The first experimental prototypes were built by the Austro-Hungarian David Schwarz in the late nineteenth century. With his theories, published in 1874, and the building of an airship, which flew successfully in July 1900, the German Count Ferdinand von Zeppelin proved the technical feasibility of a huge rigid airship, propelled by internal-combustion engines and lifted by hydrogen, with a metal frame forming the rigid structure of the airship. Although its military relevance was pointed out, from the beginning *Count Zeppelin* emphasised the commercial use of his rigid airship (de Syon 2002). It was able to solve the problem of the insufficient load-carrying capacity of the non-rigid blimps, of their size being limited for technical reasons. The Zeppelin airship overcame this limitation because it was based on a rigid, covered, but delicate aluminum frame with the lifting-gas balloons inside. This kind of airship was extremely vulnerable on land if a gust of wind caused it to crash against a barrier, such as a tree. The first Zeppelin *LZ 1*, in 1900, was 128 metres long and had a diameter of 11.65 metres; the famous *LZ 129 Hindenburg*, in 1936, was 245 metres in length and had a diameter of 41.2 metres (Hallmann 2002, pp. 29-30). After a Zeppelin landed, it

was safest to house it in a hangar: the size of the Zeppelin indicated the size of the hangar required. The building of hangars at the main Zeppelin destinations required a great deal of capital because a typical airship hangar in the 1930s was almost 360 metres long, 100 metres wide, and 55 metres high. In addition, every regular destination of a Zeppelin had to be equipped with hydrogen-producing facilities or tanks which stored this extremely explosive lifting-gas to supplement the lifting-gas which was used normally during airship operations (Knäusel 1997). Building and operating a fully-equipped airship base, which involved much more than a simple mooring mast, was therefore a very expensive investment. A similar investment at every destination could be profitable only provided a certain number of airships landed and took off. This could happen only if an adequate number of airships using this expensive infrastructure were effectively in operation. The crux in the spread of the airship was, therefore, to create a homogenous growth in the number of airships in both commercial and military operations, and in the number of suitably equipped airbases near those destinations which also attracted passengers. It was therefore vital to establish a physical airbase net as a necessary condition for the creation of an attractive network for commercial services. If this were to fail, any commercial airship service would sooner or later fail because the whole system of airships and their bases would not make sufficient profits. When was the idea of commercial services born, and when and how were attempts made to put it into practice?

In 1834, a service was proposed to connect Paris and London by means of commercial dirigible balloons. The idea of using balloons and dirigibles to transport passengers, commodities and mail on a regular commercial basis spread throughout Western Europe (Marey-Monge 1847; Steinmann 1848), and later in the United States (Leary 1985; LZA 006/0098) but could not be put into practice because of technical difficulties. In 1903, the French-Brazilian Santos-Dumont destined his airship No. 10 for passenger transportation like an omnibus, but his plan came to nothing (Mackworth-Praed 1990, p. 119). Similar examples can be found during the first decade of the twentieth century, but only Count Zeppelin in December 1909 actually put into practice the concept of regular commercial passenger airship services in Germany by founding

a joint-stock company, the Deutsche Luftschiffahrts-Aktiengesellschaft DELAG, as a division of his Zeppelin holding company. DELAG's business was to run several Zeppelins, serving a net of important German cities. The cities involved in this venture were to purchase DELAG stock and build some infrastructures such as landing grounds and hangars to protect Zeppelins on the ground from the consequences of bad weather. Until March 1914 DELAG created a net of routes connecting the German cities Frankfurt-am-Main, Düsseldorf, Gotha, the airship- and airplane-port of Berlin-Johannistal, Hamburg, Dresden, Leipzig, and the spa Baden-Oos. The service was provided by a total of seven rigid airships which, in more than 1,588 trips, transported a total of 10,197 paying passengers (Schiller 1966). During the first years, however, DELAG suffered some accidents with their airships, but without any loss of life among the passengers. The service, however, was not as reliable and regular as planned. Consequently, most of the time more expensively equipped airship-bases were in operation than airships which were able to use them. Transportation capacities which could not be sold soon caused DELAG financial loss, and it seemed that it would be a long time before civil airship services surpassed the crucial volume for profitable operation: the world's first operating network of airship services had a structure full of holes in the net as well as in the service. It was, therefore, a disaster economically. Some months before the outbreak of World War I, DELAG sold its airships, together with the net of bases, to the German military forces, and ended all commercial airship operations (LZA 018/0272). In spite of there being no commercial competition from aeroplanes, the DELAG company was not big enough to capitalise its investments by surpassing a crucial volume of passengers and destinations. The DELAG management realised this, but at the same time was convinced that a future international commercial service would be a profitable enterprise (LZA 016/0459).

Soon after the end of World War I, however, the company established two modest regular services between Friedrichshafen on Lake Constance and Berlin as well as Weimar, where the new German Parliament sat at this time. For this service a new, small, modern Zeppelin, the *LZ 120 Bodensee*, was built. An even more modern Zeppelin, the *LZ 121*

Nordstern, slightly larger than the *LZ 120*, was to start a civil airship service to Sweden soon afterwards. But when the Treaty of Versailles came into effect in 1920, these two airships were confiscated by the Allies and the afore-mentioned services came to a halt (Kleinheins 1994). Those short-lived services were technically more reliable than the Zeppelin services before World War I, but they were nowhere near rebuilding a network for passenger transportation. Since the ticket-earnings of the *LZ 120,* the only airship in operation, had to finance the total overheads of the *DELAG* company, this airship service was an economic disaster as well. No further attempt was made to establish a commercial airship network to serve Europe.

3.2 Failure to Build a Continental Airship Net in USA. The German experiences were, however, ignored by the U.S. company Goodyear. Since 1911, Goodyear had produced balloons and during World War I the company began to produce blimps. At the end of the war, a first attempt was made to produce blimps for civil purposes, but in 1919 an accident with ten victims halted this development for a short time. Because of the great interest the US Navy showed in blimps and huge rigid airships, Goodyear identified profitable economic opportunities in the construction of all kinds of airships. Therefore a joint venture was undertaken with the German Zeppelin Corporation, which in 1924 led to the construction of the *LZ 126,* later named *ZR III Los Angeles*, for the U.S. Navy to use on the North Atlantic route. This co-operation culminated in 1923 in the foundation of a jointly-owned company, the Goodyear-Zeppelin Corporation in Akron/Ohio to pool technological knowledge and to build huge rigid airships for the U.S. Navy in the future (Braun 2004; Meyer and Duggan 2001).

Using its own wartime experience, Goodyear also decided to make a further effort to establish a commercial network of airship services. Between 1922 and 1925 Goodyear had produced a small semi-rigid airship and over twenty blimps to run a modest passenger service in California (Rodengen 1997, pp. 79-80). Although we have found no data concerning the success of this service, Goodyear seemed satisfied with its success because, from 1925, the company produced a modern helium-

filled blimp, the *Pilgrim*, which was used commercially all over the United States to transport two passengers over a maximum distance of 100 miles. Until 1932 Goodyear boasted a fleet of twenty blimps, most of them larger than the *Pilgrim*, in civil operation. During the seven years of service, 92,874 passengers were transported commercially and, in 1930, the erection of a never-used mooring mast on the top of the new Empire State Building in the heart of New York was an optimistic signal (Allen 1932, pp. 95; O'Reilly 1983, pp. 65-66; Solberg 1979, p. 91; Dierikx 1997, p. 191). The literature shows different data regarding the blimps' destinations: Allen stated that the small fleet of 20 blimps operated in 42 US States and served destinations in Washington, New York, Los Angeles, Miami, Chicago, Cleveland, San Francisco, Dallas, New Orleans, and Memphis (Allen 1949, pp. 289-291). Hansen (Hansen 1977, p. 219) asserted that more or less permanent bases were in operation only in New York, Washington, Miami, Akron, Los Angeles, and Chicago. In Chicago a small base was erected on the area of the Century of Progress Exposition which was held later in 1933-34. In addition, destinations outside the USA – Toronto (Canada) and Havana (Cuba) – were mentioned. In these circumstances, this small fleet of small-scale blimps was not able to create a stable network of routes and destinations in permanent operation which could ensure a sustainable economic development. The blimps, however, had a small load-carrying capacity only because of their non-rigid construction principle. Their operation fields required only a physical net of cheap mooring masts, not the gigantic hangars the huge rigid airships needed for protection purposes. Therefore, the costs of erecting a base for blimps was much lower than for rigid airships, but the literature does not afford any data about the building and running of any base. The Goodyear blimp service was abandoned in 1932 because of the economic problems during the Great Depression. The profitable air postal service was not accessible to the Goodyear civil blimps because air postal transport in the United States was strongly regulated and only specialised firms with air-mail aeroplanes could enter this market (Rodengen 1997, pp. 83-94).

It remains clear now that in the United States, just as years before in Europe, a continental airship service did not work economically because

every attempt collapsed before it surpassed the net's crucial volume, consisting of an essential number of airbases or destinations in permanent and regular operation. This can be said of all the cases we have discussed because of the small number of airships in operation. But what happened in the rival technology of the aeroplane?

4. Development of Commercial Aeroplane Networks

4.1 Beginnings and Rapid Development in Europe after World War I. Before World War I aeroplane technology created planes far removed from any commercial consideration. Only marginal attempts at occasional and private mail transportation by the German Hans Grade (Schulz 1990) about 1910 and an anecdote about a single testing of Russia's early large-scale aeroplane *Ilia Mourumetz* in 1914 are mentioned in the literature (Haddow and Grosz 1962, pp. 66-67; Demand and Emde 1990, pp. 124-125). It is important, however, that in all European countries where individuals were engaged in developing aeroplanes or in testing their military usefulness, a rapidly increasing number of civil and military airfields emerged: in 1912 in Germany 23 airfields were in operation, and by early 1914 the number had increased to 31 airfields (Schwipps 1984, pp. 81, 107). A similar development occurred in France with more than eight airfields operating before 1909. England had seven airfields in 1913, and there were some airfields in Austria (Schmitt 1985, Prendergast 1980). Important airfields, such as Berlin-Johannisthal, were equipped with large runway areas, many smaller hangars, aeroplane factories and repair-stations, aviation-fuel-stations, terminals, and public-viewing stands (Tatzkow and Henicke 2000). As we have stated, only a small number of airfields, such as Berlin-Johannisthal, were also equipped with the very special, costly infrastructure (such as gigantic hangars) for huge rigid airships because these airships required a very different kind of infrastructure and equipment from that required by planes. A fully-equipped airbase for Zeppelins needed much more capital than a fully-equipped aeroplane airfield did. A German newspaper estimated that building the first U.S. rigid airship base, Lakehurst on the East Coast, cost some 40 million marks. The costs to build the Californian airship base,

Moffet Field, were estimated at 20 million marks (Anonymous 1935). Therefore, setting up a new airfield for planes only was much cheaper than a base for rigid airships.

An outburst of technological development during World War I made the aeroplane reliable and technically solid. Aeroplanes could be mass-produced cheaply in different sizes and on different scales and were cheap to operate – in comparison with a Zeppelin (Braun 1990). It was clear that, after the end of the war, military aeroplane technology and thousands of pilots in all countries had to be converted to civil and commercial use to deploy high-level experience and knowledge. Already in wartime some businessmen e.g. Walter Rathenau from the German firm AEG in 1917 and George Holt Thomas from the British De Havilland Aircraft Company in 1916 laid the foundations of post-war commercial aeroplane services (Wagner 1987, p. 13; Allen 1981, p. 18). In the most important European countries, commercial air transport was begun immediately by individual entrepreneurs, by plane-manufacturing firms, and shortly afterwards with governmental support (Pollog 1930, p. 6). Using former military aeroplanes or the first purely civil aeroplanes to be built, such as the German model *F 13* by Junkers, the number of commercial aeroplane services to transport passengers and occasionally mail increased (Braun 1991). In 1920 Germany already boasted a net of 25 airfields and destinations, including four destinations outside Germany, served by many regional, domestic and some foreign airlines (German Lufthansa Archive). Because of bad weather conditions, the development of domestic British aeroplane services was somewhat slower, but in December 1918 a British airline began a regular service between London and Paris; a French airline offered the same service, starting in February 1919, connecting the most important French cities and from 1921 serving destinations in Poland, Belgium, Italy, Spain and in North Africa (Fisser 1922, pp. 125-126). In 1922 in Germany 6,820 passengers were transported, in England 11,850 passengers, and in France 5,700 passengers (Allen 1981, p. 70).

Germany, geographically located in the centre of Europe and for years after World War I under various kinds of control by the victorious nations, was the country with the greatest foreign and domestic interests,

inaugurating new civil aviation routes with its neighbouring territories. In more and more European countries provision was soon made to stop competition between different national, airlines because some politicians deemed it a waste of resources and subsidies, and to ensure technical progress for military purposes. Therefore, during the whole of the 1920s, in all European countries, either voluntarily or by means of pressure from the national political bodies, airlines merged to become powerful national carriers, mostly controlled, sometimes owned, but always subsidised by national governments to reinforce the competitiveness of the national carrier compared with foreign carriers (Wüst 1927; Fürst 1936; Allen 1981; Fischer 2003). National competition between some small airlines before the merger with a national carrier led to a surplus of commercial routes within a country or nearby foreign cities because some cities wanted to be linked to the growing net of airline routes and therefore built airfields independently. Most of these destinations survived the mergers and offered the use of their airfields to the new national carriers. After the founding of national carriers, such as British Imperial Airways, the Dutch KLM, and the German Luft Hansa, competition arose between the national carriers and the governments behind them. This led inevitably to an increasing number of parallel routes and services throughout Europe, as shown in the following *Figure 1.*

Because all the other developed countries in Europe built a similar route network, it is obvious that there was no place for a competitive network of commercial airship services inside Europe. The airship had no chance of being subsidised by national governments, which were already subsidising the very rapidly growing airline services and aeroplane technology. Because of competition and due to the future military importance of aeroplanes as became evident in World War I, all European governments had voted in favour of supporting both civil and military aeroplane technology, and had voted against the civil use of airships within their own countries and within Europe as a whole. Up until the outbreak of World War II, hundreds of airports, including all regional airfields, had sprung up, forming a net which spread like a cobweb all over continental Europe and Great Britain, connecting all the important cities and some smaller towns. Based on this physical net, a network of

hundreds of routes provided a regular passenger service to all destinations. This European network of aeroplane-based passenger routes was linked to the national railway nets and the national, as well as the international, postal services (Fisser 1922; Arnoldi 1928; Altmann 1939). Was the same development seen in the United States?

4.2 Building a Commercial Airline Network in US. Invented by the Wright brothers, the use of the aeroplane in commercial services in the United States began as slowly as in Europe (Solberg 1979; Smith 1991): in November 1910, Postmaster General Hitchcock predicted that aeroplanes would be used to transport mail, but it was not until eight years later that the U.S. Army Air Service began to establish a nationwide air postal service. The U.S. Post Office adopted this idea and in 1919 began an air postal service from Chicago via Cleveland to New York. It was gradually extended to a trans-continental service to San Francisco. Thus the U.S Post Office managed aeroplanes and pilots, as well as airfields with their equipment to fuel and repair aeroplanes. Some cities tried to join this postal service network, rapidly attempting to open airfields which they financed independently. Soon both airfields and routes were equipped with light beacons for day and night flight operations. The government programmes "Model Airway" and "Air Service Reserve Flying" supported the founding of more airports by renting municipal land and financing the required equipment. Over the years the "backbone" of a continental-line from east to west was supplemented by some "side-arms". Because the range of aeroplanes was limited technically, in that they were forced to stop for refuelling every 150 or 200 miles, many airfields were built along the routes. Consequently, an estimated total of some 4,000 airfields, city airports and military airfields formed an impressive physical net (Bednarek 2001; Leary 1985). Until 1926, U.S. Post Office established a national airmail service network using aeroplanes and a physical net of well-equipped routes with beacons and airfields. In contrast with European development during the early 1920s, which laid the emphasis more on passenger transportation services than on airmail, in the United States there were no passenger services, but only airmail transport. The Kelly Act of 1925 and the Air Commerce Act of 1926 gradually established

air postal services in 1926-27, using a concession system for private enterprises. However, the U.S. Post Office defined the routes and, therefore, the structure of the net; a parallel service run by two rival private enterprises was forbidden. Some of the about 100 small and medium-sized private airlines in 1925 already existed in 1920. Some of them served a so-called "foreign mail route", for example to Cuba or to Canada (Pollog 1929, p. 58). After this kind of "privatisation", many new airways were founded, subsided by the U.S. government by means of the U.S. Post Office, and protected from ruinous competition by the concession system. Thus, some new airmail routes were soon opened to render the network more close-knit. But until 1928 passenger transport services were insufficient because airmail transportation was much more profitable. From 1930 onwards the U.S. government offered big incentives to enterprises in the airmail business to offer passenger transport services too (Pirath 1931, p. 52). Furthermore, the new Postmaster, Brown, encouraged more competition in all air services and forced the establishment of two new transcontinental routes. One consequence of the government incentives to increase competition was the creation of new, large holding companies, often a combination of airlines and aeroplane manufacturers. The airways American Airlines, Eastern Airlines, United Airlines and Trans World Airlines were examples of the emergence of large holdings which established their own networks but interconnected them with those of the others. For example, see *Figure 2*.

Pan American Airlines was a case apart, specialising in transporting airmail and later passengers solely to destinations outside the United States (Josephson 1943). Until 1933, the network of the monopolistic PanAm ranged from Mexico, the Caribbean and Central America to the South American countries: Bolivia, Brazil, Argentina, Chile, Peru, and Venezuela. Thus a net and a network for aeroplane services existed, serving both domestic destinations in the United States and important cities in the rest of the American continent. By the end of 1935 PanAm was exploring the Pacific Ocean with flying-boats to establish a monopoly for regular postal and passenger services to the Philippines, Hong Kong and Australia. Similar plans were made to fly over the North Atlantic to Europe (Hugill 1993, pp. 264-265).

During the 1920s, a dense cobweb-like physical net of well-equipped airports in the important cities and of thousands of airfields emerged all over the United States. This was used at first only by postal services, but later by passenger services too. After a process of concentration, some big private airlines, equipped with newest models from a developing national aviation industry, used this physical net, filling it with interlinked routes to all the important destinations. All these networks set up by different airways were linked to destinations in nearly all the countries of the American continent by the network created by PanAm which was in continuous expansion, as shown in *Figure 3*. Only the North Atlantic service from Europe to America seemed vacant. Was this field the sole niche for the airships to build a net and a network?

5. Intercontinental Transportation Services until 1937: a Niche for Commercial Airship Technology?

5.1 Technical Development of the Rigid Airship's Competitors. For centuries, shipping was the only means of long-range intercontinental transportation for passengers, commodities, and postal services. By the end of the 1920s, interrupted by the Great Depression, until the mid-1930s newly-built, large passenger ships were crossing the North Atlantic in less than six days, and international ship-owners' associations kept passenger ticket prices high (Brandt 1935). At the same time, some pioneer flights by Lindbergh (1927) and Köhl (1928) with very small, solo aeroplanes demonstrated that crossing the North-Atlantic by plane was technically feasible (Streit and Taylor 1972, pp. 194). These aeroplanes, however, were never intended for any commercial service. In the shadow of the Great Depression, only the very large experimental German flying-boat *Dornier DO X* showed some future possibility of a large-scale commercial transatlantic passenger service: after an experimental flight over Lake Constance with 169 passengers, in August 1931 the *DO X* reached New York to demonstrate its technical abilities (Pletschacher 1997). The German Luft Hansa company and the German government, however, did not show any interest in further development in this sector. The British airline Imperial Airways abandoned interest in the Short Brothers' flying-boats which for

some years had been flying to South Africa and India. It is to be noted that the flying-boats did not need any kind of purpose-built airports with hangars, runways, and so on. However, in the early 1930s, the land-based aeroplanes in normal use were not able to cross the North-Atlantic non-stop, but Pan American Airways made an attempt to transport mail and passengers in stages (Davies 1972, pp. 259-261; Berendt 1961, p. 43). In August 1938 a specially-equipped German *Focke-Wulf 200 Condor* flew non-stop across the North Atlantic: it was a huge air-plane which perhaps could be used for a passenger service (Dierikx 1997, p. 193; Bongers undated, 29). Was there a first-mover-advantage if airships could cross the Atlantic quicker than traditional shipping?

From 1929, an increasingly regular air-mail service using a catapult-system installed on ocean-liners divided the long-range distance into short-range distances, but for airmail transportation only. Using this method, special aeroplanes landed and took off from the passenger ships that were specially-equipped for the Atlantic crossing, and reduced the time of ship-based postal delivery from Europe to North-America remarkably (Köhler 1983). This could represent an obstacle for airship services.

5.2 Technical Predominance of the Airship: Attempts to Establish a Network versus Economic and Political Obstacles. Airship technology seemed to have an advantageous opportunity because aeroplane passenger services were not possible technically and ocean-liner voyages were very long on intercontinental routes. The advantageous technical facilities of the airship were already demonstrated in July 1919 when the British airship *R 34*, a copy of a German War-Zeppelin, flew across the North Atlantic non-stop for the first time (Maitland 1920; Abbot 1973). And so, in 1919 and 1920, some experts in the German Zeppelin Corporation discussed further plans to cross the North Atlantic with the unscathed former War-Zeppelins *L 71* and *L 72*: they also discussed projects to build a huge new Zeppelin to demonstrate the ability of German airship technology on intercontinental voyages which were planned to South America, India and the Philippines for passengers and freight (Kleinheins 1994; Hebert 2002). Between 1920 and 1923 similar plans were examined by Schütte, another firm with experience in building

huge airships since World War I. Schütte also attempted co-operation with U.S. firms to establish a North Atlantic airship service, as well as a civil airship service within the United States (Bleibler 2001). All these plans, however, could not be put into practice at the time.

After the delivery of the Zeppelin *LZ 126*, later called the U.S. Navy rigid *ZR III Los Angeles*, built in Friedrichshafen as war-reparation to the United States and brought over the North Atlantic non-stop in 1924, in Germany there was renewed enthusiasm for transatlantic commercial services using airships. However, all the other countries using airship technology, such as Great Britain, France, Italy and the United States, emphasised only the airship's military or scientific uses. After the obstacles to build airships following the Treaty of Versailles were overcome by politics in 1926, the German Zeppelin Corporation built the famous *LZ 127 Graf Zeppelin* and in 1928 completed this large-scale rigid airship which was destined for long-distance commercial travel (Schiller 1966; LZA 016/0459). These plans for the *LZ 127* were, however, thwarted by the advent of the Great Depression at the end of October 1929. During the Great Depression, which hit both the U.S. and the German economy, there was no longer a great demand for transportation services across the North Atlantic, for decades the world's most important business route (Pirath 1938, p. 70). During those years DELAG had no opportunities to use the *LZ 127* in a regular commercial service. Consequently, the *LZ 127* made many economically unimportant demonstration voyages, such as a round - the - world trip, and some scientific voyages to Arctic regions, until the global economy showed signs of recovery. By the end of 1931 a regular service had begun, however, not on the North Atlantic route but on a South Atlantic route to Brazil. This route was chosen because some representatives of the principal German ship-owners on the board of the company had intervened. It was in their interest to protect their newly-launched ocean-liners *Bremen* and *Europa* on the North Atlantic route from competition from the airship which crossed the ocean in almost half the time of these two ships. On the South Atlantic route the Zeppelin did not trouble ship owners' interests; so *LZ 127* served North-Atlantic route casual only. Therefore, a mooring mast, a huge hangar were erected in Pernambuco, Brazil, together with all the other necessary

equipment, and also in the intermediate station in Spain, subsided by German government (Knäusel 1997, p. 344; de Syon 2002, p. 174). Because the route from Europe to Brazil was served only by slow post-steamers without any comfort for passengers, the passenger fare for the Zeppelin was set high: in 1934, for example, the price of a passenger-ticket for the *LZ 127* from Friedrichshafen to Pernambuco was 1,550 Reichsmarks during the high season (Bruer 2002, Appendix).

In the United States, in 1919, the U.S. Navy began to install an airship infrastructure gradually at Airship Base Lakehurst, New Jersey, near New York. From 1930 several U.S. merchant airship bills were introduced in the U.S. Congress, and so commercial airship services seemed to have a flourishing future: Lakehurst was fully equipped as an international airship base. But it was to be used mostly by the U.S. Navy Zeppelin *ZR III Los Angeles* and the new two giant U.S. Navy airships under construction (Althoff 1990). One of these airships, the *USS ZR4 Akron*, came into operation in 1931 and was to fly over the Atlantic Ocean, but met with an accident in April 1933. The other airship, the *USS ZR5 Macon*, came into operation in 1933, and was to be based at the new airship base Moffet Field on the Pacific coast, but it met with an accident in February 1935. Because of these accidents, the German civil Zeppelin *LZ 127* was able to use the U.S. Navy base at Lakehurst only occasionally while the *Akron* was operating (1931-1933) and this, together with the ship-owners' interests, was another valid reason for preferring the South Atlantic route. The accidents involving the huge rigid naval airships *Akron* and *Macon* had, however, important consequences: following the U.S. Army which had already abandoned the use of rigid airships in the mid- 1920s, the U.S. Navy now immediately cancelled all its former ambitious plans to build a fleet of rigid airships; by 1934 the *ZR III Los Angeles* was no longer in service (Robinson and Keller 1982; Smith 1965). After the Goodyear company had given up the continental market for passenger services using blimps in 1932, as the manufacturer of *Akron* and *Macon* it had at that time no further interest in investing in long-distance commercial air-shipping, just like other private U.S. investors. By 1935 not a single huge rigid airship was in operation in the United States, but the fully-equipped international airship base Lakehurst on the Atlantic coast still existed.

Thus, there was an advantageous opportunity for the German Zeppelins to begin a regular service on the North Atlantic route. The project was supported by the Nazi government in power in Germany since 1933 because the Nazis were keen to earn stable foreign currency. And so, in the summer of 1936 the newly built giant Zeppelin *LZ 129 Hindenburg* went into commercial operation to serve the North Atlantic route with regular departures from Frankfurt-am-Main in Germany to Lakehurst until the disaster on 6 May 1937. In spite of the fact that *LZ 129* was not always fully booked for the North Atlantic crossing, the Zeppelin company earned US dollars from the sale of passenger tickets and the transport of mail: about the same price as a first-class-ticket on a modern passenger-liner, a one-way-ticket from Lakehurst to Frankfurt-am-Main on the *LZ 129* cost about 400 Reichsmark (Marschall and Archbold 1994, p. 170). But the functioning of the, by now, only two huge rigid airships in operation worldwide depended on subsidisation by the Nazi government and the German carrier Luft Hansa *(LZA 006/0668; LZA 006/0757).* These two airships were nowhere near establishing an economically sustainable net of interlinked destinations: the two routes mentioned were point-to-point services only and were not well synchronised with other means of transportation. The Zeppelin *LZ 130 Graf Zeppelin II,* which was completed at the time of the Lakehurst disaster, had never entered into commercial operation, in spite of the fact that this airship was destined to replace the ten-year-old *LZ 127 Graf Zeppelin* with its limited commercial load-carrying capacity. A further Zeppelin of the Hindenburg class, the *LZ 131* was only in the very early stages of construction when *LZ 129* exploded (Bauer and Duggan 1994). Because the Nazi regime stopped all commercial services of the *LZ 127* and the new *LZ 130* immediately after the Lakehurst disaster, the net of the small number of airbases used at Lakehurst, Frankfurt-am-Main, in Spain, Brazil, and in the Zeppelin shipyard Friedrichshafen became commercially valueless.

But what happened to commercial airship services in other countries? Why did the point-to-point routes between the United States, Germany and Brazil remain a singular phenomenon?

In Great Britain in the mid-1920s a plan for a London-based worldwide net for twelve huge rigid airships was under consideration. Developing

routes suggested by airplanes proved to be to slow and burdensome. Five routes from London via Egypt to India and Australia, to Canada, two routes to Central America, and an eastern as well as a western-bound route over Africa to Cape Town were to be established, providing a governmental courier service (Beelitz 1927). Soon mooring masts were erected in England, in Egypt, in Canada and in India, forming a net for the first routes. This ambitious British project may be regarded as a strong move to create a network of airship services throughout the Empire, and it can be argued that similar airship services belonging to other countries, such as Germany, could in theory be linked to this British "backbone". Therefore, the first airships to carry out this project were built and the first airship, the *R 100,* designed for 100 passengers and 10 tons of mail, crossed the North Atlantic in July 1930 and reached its mooring mast in Montreal without any problem. The return voyage took only 57 hours and the *R 100* landed at its British base at Cardington. The next airship in this project, the *R 101,* designed for 50 passengers, began its first regular voyage to Egypt and then to India on 1 October 1930 but crashed over France and all the passengers were killed. Because of this disaster, the ambitious British project was terminated immediately and a real opportunity to create a large-scale network of commercial airship services was lost in 1930 (Chamberlain 1984; Higham 1939; Higham 1960; de Syon 2002, p. 189). The mooring masts erected in Ismailia, Egypt, in Karachi, India and in Montreal, Canada, had been preserved for some years to ensure an option in air-shipping in the future (Countryman 1982; Countryman 1992, pp. 90-91). A small British syndicate remembered this infrastructure and, in the light of the first successful voyages of *LZ 129 Hindenburg* in 1936, proposed co-operation between the newly-founded British Zeppelin & Airship Navigation Syndicate and the Deutsche Zeppelin Reederei, the new corporation that followed *DELAG.* It was suggested that the very ambitious project should be based on up to eight Zeppelins of the *Hindenburg* class and should create a worldwide network of regular commercial routes linking Great Britain, Germany, other European countries, the United States, Canada, South America, South Africa, Egypt, India, Australia, and countries in the Far East (Edmonds 1936). The rudimentary physical net of mooring masts and some bases in England, Germany, Brazil, Spain, on the east and west coasts of the United States, in

Canada, in Egypt, and in India did exist. At the same time in the Netherlands it seemed that there were vague plans afoot for a regular airship service from Amsterdam to Batavia in Dutch Indonesia because the KLM aeroplane service since 1932 had an insufficient load-carrying capacity and the journey lasted ten days with eight stops (Kaefer 1999, pp. 17-18; LZA 005/0601). All these projects, however, seemed wishful thinking on the part of airship-enthusiasts in some countries and collapsed totally when the *LZ 129 Hindenburg* crashed.

Nevertheless, it was recognised that the establishment of a worldwide net of airship bases was vital to run any commercial services successfully and to form a network. Only if all the projects under consideration during the 1930s had been carried out would rigid airship technology have survived and been able to compete with the beginning of intercontinental airplane routes. In the mid-1930s, the technology of huge rigid airships for covering large distances under all climatic conditions was fully developed and more advanced than that of contemporary aeroplanes in the same field of operation. It seemed that the huge rigid airship had a so called first-mover-advantage in creating a net and a network before the airplane was able to do so. Airship-technology had been able to occupy the intercontinental services market with air-transportation and this perhaps had deterred aeroplane-based services from risking entering the market some years later. Those who supported the different national airship companies, however, did not co-operate with their net projects and evidently lacked the capital necessary to finance these huge investments. Furthermore, most governments gave massive support to the aeroplane and its networks because this means of transport seemed extremely important for future military purposes. When, in one single country, an airship met with an accident, airship technology as a whole came to an end.

6. Conclusion: History Repeats Itself

The most important result of our analysis has been to reveal the importance of how quickly net-building surpassed a crucial number of operation bases, a preliminary condition for establishing service networks. In all countries, the airport and airfield net grew faster than the airship-base

net. The slower-developing and, therefore, losing technology, together with its services, existed only until a huge disaster, and then was promptly abandoned. Before this, however, long-term economic losses were tolerated.

Here, history does repeat itself as is seen the shutdown of the Franco-British supersonic aircraft, *Concorde*. Like the late Zeppelins, the *Concorde*, with its inaugural flight in 1969, was designed for very high speed, long-distance transport. This aircraft was very complex and expensive, both in capital costs and running costs. At first, about one hundred potential buyers signed options to purchase this aircraft (Wilson 1973; Feldman 1985). However, administrative barriers soon limited the service to North Atlantic crossings, connecting New York and London, and New York and Paris only. Therefore, the establishment of a worldwide net of supersonic services was impossible to achieve, and only a dozen of these aircraft went into regular service. But thirty years later and after a terrible accident, the commercial operations of all *Concorde* aircraft were immediately shut down in 2000, just like the Zeppelins in 1937. After a long struggle against its big, but cheap, rival, the *Boeing 747*, the technically more sophisticated *Concorde* was knocked out of the market just like the sophisticated technology of the Zeppelins was in the overall fight against the aeroplane. The historical event which removed the great rigid airship from the market was the Lakehurst disaster, combined with the U.S. policy of refusing to save helium-gas to lift Zeppelins to Hitler's Germany (Braun 2005). In the case of the *Concorde*, rapidly rising prices for aviation fuel because of the oil crisis and growing concern about damage caused by noise pollution were historical events that stopped any attempt to reach a crucial number of destinations. The accidents were obvious reasons to terminate both the Zeppelin technology and the Concorde technology. Both failed economically because they were not able to establish a network of routes and destinations equal to the important rival technology responsible for the technically and economically improved aeroplane.

But some people do not learn from history: the failure of the German-invented magnetically levitated train, the *Transrapid*, has the same basis as the huge rigid airship and the *Concorde*: *Transrapid* technology was sophisticated and expensive in comparison to the long-standing, well-established networks of its technical rivals, the modern railway, the short-

range aeroplane and the automobile. Nobody financed the enormous investments to install a totally new net for a *Maglev*. The *Airbus 380*, designed for a small number of hubs, versus the rival *Boeing Dreamliner* is a concrete present-day example of the importance of nets and networks. Because the *Airbus 380* requires expensive airport equipment, such as longer runways, better passenger logistics, and giant hangars for preventive maintenance, airports will have to make large investments in this specific infrastructure. Will a crucial number of airports worldwide really make these investments?

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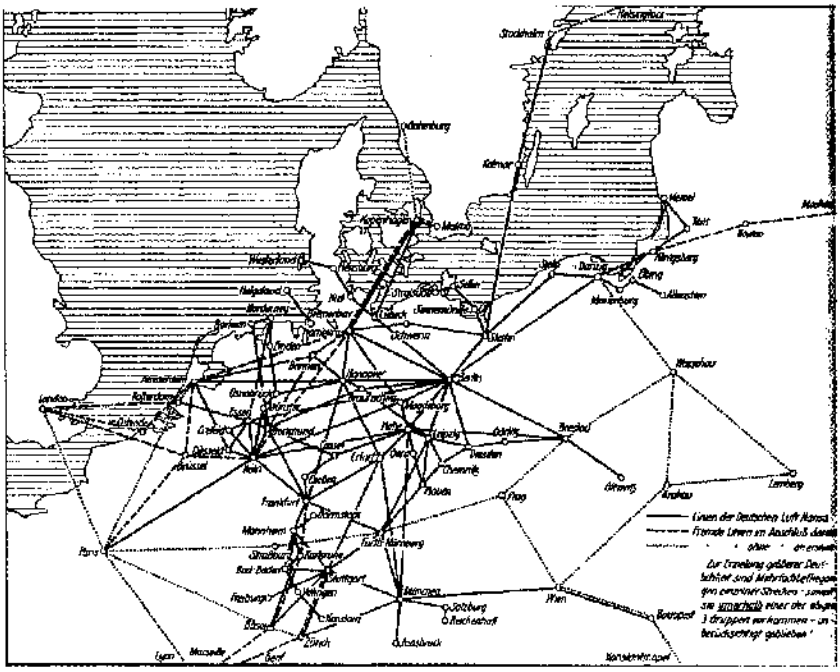
Appendix

Lighter-than-air v. Heavier-than-air: How can Network Effects Explain the Failure of Airship-Technology?

FIGURE 1. Network of routes and destinations by the German company Luft Hansa in 1926

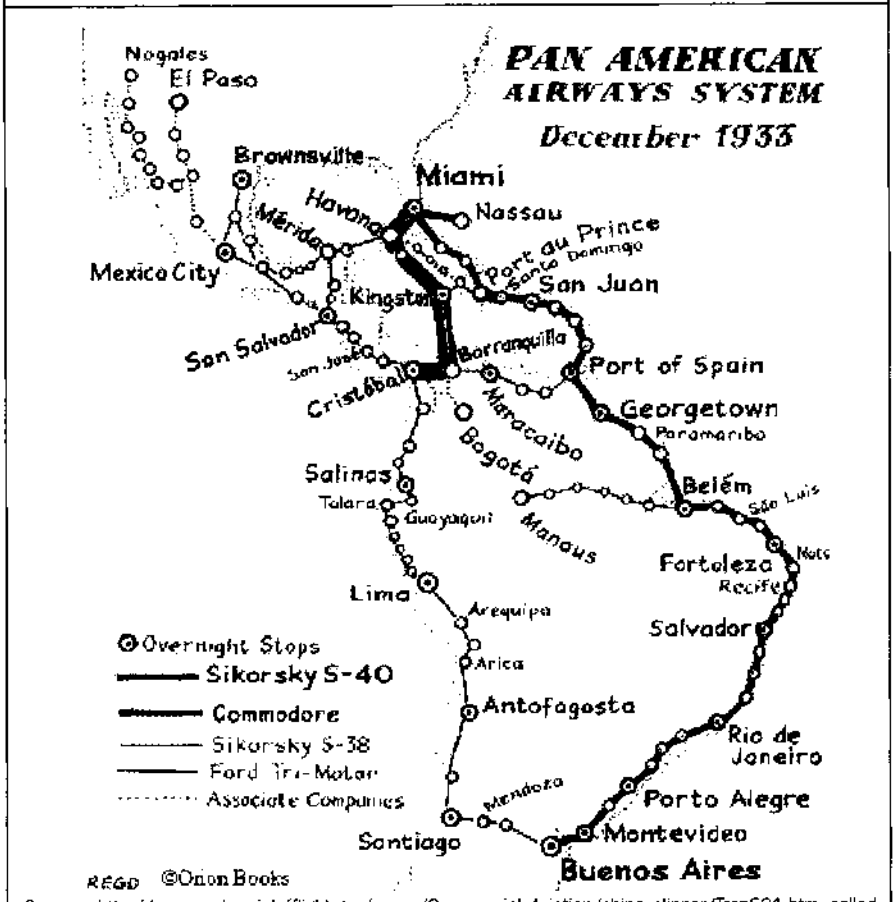


Sources: from the archive of Deutsche Luft Hansa, Ordner Flugpläne 1926-1933, (Cologne).

FIGURE 2. Network by American Airlines in the year 1934 as one example only

Sources: http://www.timetableimages.com/ttimages/aa3406i2.htm, called 29 August 2006).

FIGURE 3. Pan American Airways System in 1933



Sources: http://www.centennialofflight.gov/essay/Commercial_Aviation/china_clipper/Tran5G1.htm. called 29 August 2006)

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