RECENT CHANGES IN AMERICAN TRANSPORTATION AND THE FUTURE OF TRANSPORT BY AIR

FRANK RANSOM STRONG

I

In the last ten to fifteen years, or approximately since the time of the Great War, there has appeared a very distinct change in American transportation, one that augurs much of significance for the future. It is, essentially, a change involving the development of new and significant modes of transport in addition to those forms which were of importance prior to the War Years. Much has been written and said regarding this very important development in transportation and the purpose of this paper will be to set forth briefly its general nature and then to proceed to discuss something of the future possibilities of one of these new modes, that of transport by air. In many ways this type of movement may be regarded as the newest of the new, for it involves the use of an entirely new medium. The transportation of a person or goods necessitates the employment of two things, a permanent way and a moving mechanism. Either one is valueless without the other; they are both necessary in any transport. In all the other types of transportation which man has devised, from the most primitive to the most advanced, the permanent way has been either land or water in some form. The airplane represents man's first use, in the actual transport of persons and goods, of air as a permanent way.

In order to grasp the full significance of this recent change in American transportation it will be of value to

* The term "transport by air" is here used to mean air transport with heavier-than-air craft. Transport by lighter-than-air craft has not yet developed beyond the experimental stage in the United States. By "American transportation" is meant the carriage of passengers and freight in domestic commerce, but excluding movements within cities and towns. What is included may be described as inter-city and inter-regional transportation.

† Instructor in Economics.
consider the status of transport in the United States previous to the World War and then to contrast this with transportation as it now exists in America. Upon an examination of the pre-war conditions in transportation the fact presents itself that during the period extending, roughly, from the Civil War to the World War the terms "railroad" and "transportation" were nearly synonymous. It was a time during which the railroad, itself a newcomer in the third decade of the nineteenth century, was predominant in the field of transportation.

Transport by turnpike had disappeared and the highways of that era were for the most part in a state of disrepair and neglect, maintained only in a limited way by local road overseers. The railroads had likewise, by the latter part of the century, established their supremacy over canal and river transport and that mode of carriage, which had been of such importance in the early years of the century, was of less and less significance with each passing decade. On the other hand, the motor vehicle and the airplane were, as modes of transport, of no significance in this period, although a great deal of fundamental technical progress was being made in connection with the development of the internal combustion engine, the study of flight in heavier-than-air craft, and the development of scientific highway construction. Moreover, the use of the pipe line in transportation, intercoastal movements via the Panama Canal, and hydroelectric power transmission were all transport agencies of the future.

It is not to be inferred from this, however, that the railroad was, during these years, the only factor in transportation. There existed other modes of transport of significance during a part or the whole of this period—coastwise transport, the Great Lakes traffic, and the

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1 The year 1860 is usually considered as the date marking the establishment of railroad supremacy over canal and river, yet canal traffic in particular was still of importance until about 1875 or 1880. Thus in the case of the Erie Canal, the tonnage carried in 1873 exceeded that carried by either the Erie Railroad or the New York Central Railroad. See, Report of the Inland Waterways Commission, 1908, p. 227.
interurban electric railway.\textsuperscript{2} Transportation on the Great Lakes and along the Atlantic and Gulf coasts was an important mode of carriage during the whole period, while coastwise transport on the Pacific was of significance during the latter part. Thus traffic on the Lakes, instead of decreasing as did that on rivers and canals, increased steadily until about the end of the World War, since which time it has remained at approximately the same volume. This increase through the period under consideration is indicated by the fact that in 1868 the gross tonnage of steam vessels on the Great Lakes was 144,117 and in 1920, 2,856,555.\textsuperscript{3} And the interurban electric railway was a factor in American transportation during the latter part of this period, its time of growth and significance having been between about 1890 and the War Years.\textsuperscript{4}

These three modes of transport other than the railroad were of importance, then, during this general period. Yet they were to a great extent specialized types of carriage, necessarily limited in scope and significance, and in no way compared with the railroad and the position which it held. It is therefore correct to conclude that although in this period there were several forms of transport, the railroad was the \textit{one} great factor in the carriage of passengers and freight.

\textsuperscript{2} It is to be noted that in the discussion of this period no mention is made of the transportation of crude oil by pipe line. This mode of transport did have its beginning during this period, but the director of the Bureau of Railway Economics is authority for the statement (see \textit{Mechanical Engineering}, March, 1931, p. 180) that it did not play an important part in the movement of crude (oil) until about the time of the World War. It is only during the last ten to twenty years that the pipe line has come to be the major carrier of this mineral product—before this, the greater part of crude petroleum was handled by the railroad. Hence for the purpose of this article, which seeks to outline something of the recent development of new, significant types of transport, it seems entirely correct to consider the pipe line movement of crude oil as a development of a later period.

\textsuperscript{3} Commissioner of Navigation, Merchant Marine Statistics, 1925, p. 9.

\textsuperscript{4} See U. S. Census Bureau, \textit{Census of Electrical Industries}, 1927, p. 5. The Census Bureau does not distinguish between urban and interurban electric railways but the development of the two was substantially the same in point of time and importance.
### TABLE I

**RELATIVE IMPORTANCE OF VARIOUS TYPES OF TRANSPORT**

#### Passenger Movements

<table>
<thead>
<tr>
<th>Mode</th>
<th>Passenger-Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I Steam Railroads</td>
<td>26,821,000,000</td>
</tr>
<tr>
<td>Coastwise Transport</td>
<td>Unknown</td>
</tr>
<tr>
<td>Great Lakes</td>
<td>28,226,185 passengers</td>
</tr>
<tr>
<td>Interurban Electric Railways</td>
<td>1,180,867,000 passengers</td>
</tr>
<tr>
<td>Interurban Motor Transport</td>
<td></td>
</tr>
<tr>
<td>Commercial (for hire)</td>
<td>9,940,000,000 passenger-miles</td>
</tr>
<tr>
<td>Private (corporate and personal)</td>
<td>153,450,000,000 passenger-miles</td>
</tr>
<tr>
<td>Total</td>
<td>163,390,000,000 passenger-miles</td>
</tr>
<tr>
<td>Inland Waterways</td>
<td></td>
</tr>
<tr>
<td>Pipe Line Transport</td>
<td></td>
</tr>
<tr>
<td>Crude Oil</td>
<td></td>
</tr>
<tr>
<td>Natural Gas</td>
<td></td>
</tr>
<tr>
<td>Gasoline</td>
<td></td>
</tr>
<tr>
<td>Intercoastal Transport</td>
<td>122,938,000 passenger-miles</td>
</tr>
<tr>
<td>Hydroelectric-Power Transmission</td>
<td></td>
</tr>
<tr>
<td>Air Transport</td>
<td></td>
</tr>
<tr>
<td>Commercial (for hire)</td>
<td>108,000,000 passenger-miles</td>
</tr>
<tr>
<td>Private (corporate and personal)</td>
<td>33,900,000 passenger-miles</td>
</tr>
<tr>
<td>Total</td>
<td>141,900,000 passenger-miles</td>
</tr>
</tbody>
</table>

#### Freight Movements

<table>
<thead>
<tr>
<th>Mode</th>
<th>Ton-Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class I Steam Railroads</td>
<td>422,117,000,000</td>
</tr>
<tr>
<td>Coastwise Transport</td>
<td>124,998,075</td>
</tr>
<tr>
<td>Great Lakes</td>
<td>97,322,360,000</td>
</tr>
<tr>
<td>Interurban Electric Railways</td>
<td>1,270,000,000</td>
</tr>
<tr>
<td>Interurban Motor Transport</td>
<td></td>
</tr>
<tr>
<td>Commercial (for hire)</td>
<td>2,034,648,000 ton-miles</td>
</tr>
<tr>
<td>Private (corporate and personal)</td>
<td>9,268,952,000 ton-miles</td>
</tr>
<tr>
<td>Total</td>
<td>11,303,600,000 ton-miles</td>
</tr>
<tr>
<td>Inland Waterways</td>
<td>8,660,420,414 ton-miles</td>
</tr>
<tr>
<td>Pipe Line Transport</td>
<td></td>
</tr>
<tr>
<td>Crude Oil</td>
<td>35,000,000,000 ton-miles</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>60,700,000 (coal)</td>
</tr>
<tr>
<td>Gasoline</td>
<td>Unknown, but insignificant</td>
</tr>
<tr>
<td>Intercoastal Transport</td>
<td>64,383,413,000 ton-miles</td>
</tr>
<tr>
<td>Hydroelectric-Power Transmission</td>
<td></td>
</tr>
<tr>
<td>Air Transport</td>
<td></td>
</tr>
<tr>
<td>Commercial (for hire)</td>
<td>104,000 ton-miles</td>
</tr>
<tr>
<td>Private (corporate and personal)</td>
<td>589,000 ton-miles</td>
</tr>
<tr>
<td>Total</td>
<td>693,000 ton-miles</td>
</tr>
</tbody>
</table>

In marked contrast to this period extending approximately from the Civil to the World War, there stands out the present period, the period beginning, roughly, with the close of the Great War. As is apparent upon the briefest reflection, it is a period of many new and im-
portant modes of transport. The nation not only enjoys the forms of transportation in use before the War, but there is developing in ever-increasing significance transport by motor on the highway, transport by pipe line, transport by inland waterway, intercoastal transport via the Panama Canal, transport by air, and hydroelectric-power transmission.

It would indeed be difficult to overestimate the importance of this change. The old organization of transportation centering around the railroad, that existed in the earlier period, has been disrupted. New types of transport have appeared to take a part in the carriage of passengers and goods. The dominant position which the railroad enjoyed has been challenged and the whole of American transportation is in a state of flux. A new alignment, a new relationship, in transportation, based on these recent and important developments of this present period, is of necessity gradually evolving. The paramount question of the time is: what will be this new relationship, this new alignment? What part will each mode of carriage play in the totality of future transportation? Of what nature will that part be and of what significance? In brief, what does the future hold for the various forms of transport? These questions are of vital concern to the transport agencies affected, the industries of the nation, and the general public. To the transport agencies, because their future significance, earning power, and status in the security markets is involved; to the industries, because future costs of transportation, so important in modern business, are involved; and to the general public, because transportation is, in a very real sense, at the basis of the nation’s economic, social, and political life.

It is not peculiar, then, that comments upon this changed condition in American transportation have been of late almost without number. Thus the Interstate Commerce Commission, in its annual report to Congress for 1930, after pointing out that the recession in business had affected the railroads adversely, went on to
observe that a "different and more threatening financial difficulty confronts the railways. This is the effect of the competition of other forms of transportation." The Director of the Bureau of Railway Economics, Julius H. Parmelee, makes a similar observation in a recent publication of the Bureau. He says: "While the railways faced many problems in 1930, growing out of the worldwide depression of that year, they also confronted a number of economic problems not related to the depression. The greatest of these was the rising tide of competition from other agencies of transportation, which some have thought might eventually engulf the railway industry."

In order to appraise this change in American transportation, the writer has endeavored to determine from available information the present relative importance of these new modes of transport as compared with those transportation agencies, especially the railroad, that were important factors before the World War Period. The results of this study are given in Table I. An effort was made to secure the latest figures on all the various forms of transport. Information regarding the amount of coastwise passenger transport and the volume of gasoline moved by pipe line is, however, unobtainable, while in the case of some of the others the figures are those of 1929 or before rather than of 1930. Again, insofar as possible, all figures for the various types of transport were reduced to a strictly comparable basis through the use of the passenger-mile and ton-mile units of measurement, but in some cases it was impossible, because of lack of information, to do this. Even where such a reduction was possible, it was necessary in some instances to rely in part on estimates. These estimates were in every case, however, made on what seemed to be reasonable bases. But although these statistics are not altogether complete, nor entirely accurate, nor in some cases strictly

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comparable it is believed that they give a reasonably correct and inclusive picture of the relative significance of the newer and older forms of transportation. A discussion of the manner in which these statistics were determined will be found in the Appendix. Finally, it should be stated that the measures of relative importance that are used in the great majority of instances, the passenger-mile and the ton-mile, are the measures of traffic magnitude commonly employed in statistical studies in the field of transportation. A passenger-mile denotes the carriage of one passenger for the distance of one mile; a ton-mile is the measure of the movement of one ton the distance of one mile. Thus to measure the total passenger-miles handled by any mode of transport, it is necessary to multiply the total number of passengers moved by the average ride per passenger; and to measure the total ton-miles, it is necessary to multiply the total number of tons moved by the average distance of movement per ton.

These figures reveal a number of significant facts in both passenger and freight transport. In the case of passenger carriage, the outstanding fact is undoubtedly the enormous movement of passengers in inter-city traffic by motor transport. It is to be especially noted, too, that by far the greater amount of this motor transportation is performed by the private automobile. Clearly, the motor bus is an important factor in the present-day movement of passengers, but the private car is a far more important factor. The interurban electric railway appears, from what information we have, to be still of significance despite the relative decline since the War of this form of transport. Intercoastal, air, and lake transport are only of secondary importance and the same is without doubt even more true of the carriage of passengers in coastwise transport, although figures on this mode of carriage are not obtainable. Hydroelectric-power transmission and inland waterway and pipe line transport are not concerned with the movement of passengers. A glance at the magnitude of the passenger-
mileage credited to the railroads indicates that this agency is still of very great importance in the field of passenger transportation but that it is overshadowed by the immensity of the motor transport passenger-mileage. It is the motor vehicle, primarily the private motor car, which explains almost entirely the decline in passenger traffic that American railroads have experienced since the end of the War Period. Without considering the abnormal year of 1930, a year greatly affected by adverse business conditions, the problem the railroads face is briefly this: during the thirty-year period ending with 1920, passenger traffic increased more than six per cent annually; from 1920 to 1929 this type of traffic decreased more than three per cent each year.  

A consideration of the figures on freight carriage reveals that the railroad is by far the greatest mover of freight. However, there are now many other carriers of freight, of which the Great Lakes, crude oil pipe lines, and intercoastal vessels are clearly of great importance. Inland waterway, coastwise, and motor truck transport are of lesser, but nevertheless real, relative importance. It is difficult to estimate the relative significance of hydroelectric-power transmission and of the movement of natural gas by pipe line. In order, however, to make possible some fairly accurate estimate, figures on total kilowatt-hours of electricity and on cubic feet of natural gas were reduced to a comparable basis by determining the number of tons of coal displaced as a result of the use of natural gas and hydroelectric power. This procedure, by indicating the amount of coal that would supposedly have been moved if there had been no transmission of electrical energy and no movement of natural gas, indirectly gives some idea of the importance of these two new modes of transport. After reducing these figures to a ton-of-coal basis, it appears that hydroelectric-power transmission and especially natural gas movement by

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8 *Railroad Data*, November 28, 1930. Published weekly by the Committee on Public Relations of the Eastern Railroads, 143 Liberty Street, New York.
pipe line are of importance, probably more so than inter-
urban electric railway carriage. Finally, it is to be
noticed that air transport and gasoline transport by pipe
line are relatively insignificant, but it must be borne in
mind that these are very recent forms of transport and
that their significance is primarily potential. In the case
of pipe line movement of gasoline, it has been stated
recently that some rail officials believe it to constitute a
serious menace to their form of carriage.⁹ It appears,
then, that while the railroad is the major carrier of
freight, it has many competitors whose combined
strength is very great. Their effect on the railroad as a
mover of goods is indicated by the fact that, again dis-
regarding 1930, the freight traffic of the railroads in-
creased less than one per cent each year during the years
from 1920 to 1929, while in the thirty-year period con-
cluding with 1920 freight traffic increased more than
seven per cent annually.¹⁰

Out of this tremendous change in the transportation
pattern, there arises the fundamental question as to what
part each mode of transport shall play in the future.
It is a question of great practical import for all these
different types of carriage and for the railroads espe-
cially. With a great deal of consideration and discussion
being given at the present time to the question of the
future of such modes of transport as the railroads, the
inland waterways, the motor bus, the motor truck, the
pipe line, the interurban electric railway, the private
automobile, and others, it seems highly worth-while to
give some consideration to the future of one of the newest
among the various modes, that of air transport. In con-
sidering this question of the place of air transport in the
total transportation system of the future, as indeed in
considering the future of any of the new types of trans-
port, it is essential to bear in mind the fact that no new
types of carriage have ever supplanted the older pre-
iously existing types. From the Asiatic beast of burden

⁹ Flynn, “Battle by Rail,” Collier’s, April 4, 1931, p. 68.
¹⁰ Railroad Data, November 28, 1930.
and the Indian travois to the present methods in transportation, brief reflection indicates that newer forms have only supplemented, not supplanted, older forms. A recent writer has expressed this fact very clearly, pointing out at the same time its significance in our present study. "No means of transportation has ever entirely supplanted any other. Each of them, from domesticated pack animal, dugout canoe, and wheelbarrow, to the canal barge, the locomotive, the bicycle, and the automobile, has eventually found its place as a supplement to all the others. No agency of locomotion has ever been discovered but what has retained . . . its human usefulness for some purpose in some place, despite subsequent invention of new agencies. From the historical standpoint, therefore, it appears that the fundamental problem confronting aeronautics as an industry is the determination of what particular type and range of transportation service it can economically provide." 11 A consideration of the future possibilities of transport by air thus clearly resolves itself into an examination of the kinds of transportation service for which the airplane is peculiarly suited.

A consideration of the nature of the heavier-than-air craft and of its development since the War seems to indicate perhaps three major facts regarding the place of airplane transportation in the future aggregate transportation system. These are: first, that the carriage of mail will be of less and less importance as air transportation develops; second, that the airplane will be the carrier of those goods and passengers for which speed and the saving of time are of value; and third, that the airplane will, as a freight carrier, transport in the main goods having great value in proportion to bulk and weight.

"Air mail," it has been stated in one treatise on airplane transport, "has been the foundation of air traffic

development in the United States.\textsuperscript{12} No greater truism than this could be expressed, for the development of air transportation in the United States up to the present time has been, to a very great degree, predicated upon the carriage of mail under contract with the Post Office Department. Even at present air transport is dependent on air mail, for, with few exceptions, the lines not carrying mail are still financially unsuccessful. One writer has recently summed up the past and present situation with the statement that it is "unquestionable that a very large portion of the existing system of commercial air transport has been established in reliance upon, and continues to depend primarily upon, the revenue from carrying the mails."\textsuperscript{13} Yet air mail, although it has been and still is of such importance, will without doubt be of ever lessening significance as the airplane continues to develop, as it has in the last few years, from a more or less specialized carrier of mail into a great agency for the movement primarily of passengers and freight, both commercially and privately. That this will be the future trend is indicated clearly by several recent comments of importance. Thus in discussing air transport progress during 1930 the Editor of \textit{Aviation} states that "It is to be expected that air mail will play a constantly less important rôle in air transport operations after 1931."\textsuperscript{14} Again, the National Advisory Committee for Aeronautics, the committee established by the Congress in 1915 for the "supervision and direction of the scientific study of the problems of flight," after discussing the early stages of airplane development, remarks that "As the fourth stage (of development) we may expect to see the carrying of passengers and express become the major portion of the business of the operating air lines and the carrying of mail become subordinate."\textsuperscript{15} And further-

\textsuperscript{12} Woolley and Hill, \textit{Airplane Transportation}, Hollywood, 1929, p. 201.
\textsuperscript{14} \textit{Aviation}, January, 1931, p. 19.
\textsuperscript{15} Sixteenth Annual Report, National Advisory Committee for Aeronautics, 1930, p. 1.
more it is to be borne in mind that the further development of private flying, a development necessarily totally independent of the carriage of mail, will clearly reduce the significance of air mail to a still greater extent. Airplane transportation will assuredly find its place in the aggregate of transport as a carrier principally of passengers and goods.

There can be no question but that in the future, as in the past, speed will be the great advantage of the airplane as a means of transport. It is a feature which follows directly from the very nature of heavier-than-air craft. Transport planes at present travel at the rate of from 90 to 135 miles per hour and private planes have about the same speed range. The all-air transcontinental service of Transcontinental and Western Air, Inc., calls for an average over-all speed of approximately 94 miles per hour, a speed which for the entire distance between New York and Los Angeles bettered by some sixty hours the fastest rail time. Moreover, recent technical developments and flights point to much greater speeds in future private and transport flying. Perhaps the most noteworthy indication of such possibilities is to be found in the recent achievements of Captain Frank Hawks. Flying the now famous Travel Air Mystery Ship, Captain Hawks during the course of 1930 averaged 179 miles an hour in an east-west transcontinental trip and from 190 to 270 miles per hour in various flights between important Eastern cities. It is most certain that the airplane will be the mode of transport in all those cases where time is the significant factor.\(^{16}\)

In considering this element of speed, however, it must be remembered that it is not speed itself but rather time saved which is the important consideration in airplane service. Thus the greater speed in flight may be offset by terminal delays, the final result being a failure of the airplane to effect a saving in time over other means of transportation. The same result may obtain

\(^{16}\) For further information regarding recent developments in greater speed, see the *Aircraft Yearbook for 1931*, Chapter VIII.
where slower modes of transport can utilize night travel to balance greater air speeds by day, although the development of simplified night flying will seriously mitigate such possibilities. On the basis of these and similar observations it has in the past been contended that airplane transportation would be limited essentially to long-haul operations of perhaps 500 miles or more. For instance, in the Report on Civil Aviation made in 1926 by the Department of Commerce and the American Engineering Council, emphasis is placed on long-distance transportation. "One of the major services which flying can render consists in carrying goods and passengers at high speed over considerable distances where the time saved can be of great commercial value."17 The recent inaugurations and now successful operation, however, of the Ludington Air Line from New York to Washington and of Air Ferries, Ltd., operating between San Francisco and outlying cities across the bay, indicates that the airplane also has possibilities as a time-saver in short-haul operations. The Pacific Coast Editor of Aviation last year made the comment that "The outstanding success which has attended the service inaugurated by Air Ferries, Ltd., has lent new significance to the possibilities of short-haul air services as they might be made to fit into the transportation pattern of many portions of the country."18 In a review of 1930 Air Transport Progress the Editors of the same publication remark at a later date on the special significance of the success of short-haul airlines established during 1930 and in another connection state that, in particular, "The organization of the Ludington Line to operate an airplane service every hour on the hour between New York, Philadelphia and Washington, where it is forced to compete with one of the best railroad services in the country in

17 Civil Aviation, A Report by the Joint Committee of the United States Department of Commerce and the American Engineering Council, McGraw-Hill, 1926, p. 13. Mention of other "major services" does not appear to be a reference to short-haul operations, but rather to air mail service and to industrial uses of the airplane such as crop dusting, forest patrol, etc.

18 Aviation, June 7, 1930, p. 1120.
time between terminals, safety, reliability, comfort, and rates, over a route only 200 miles long, is without doubt one of the boldest recent developments in the entire field of transportation." In view of these recent developments, then, it would seem that the airplane will in the future perform all those transport operations, of whatever distance, where great speed can effect a saving in time that is of economic or commercial value.

The future significance of the airplane's ability to effect substantial reductions in the time necessary in transport has already been indicated in part by the developments that have taken place up to the present time. To mention a few, the movement of money in domestic trade has assumed importance in the banking world as a result of the saving in interest that is possible. Another development that will apparently be of great significance in the future is the utilization of the airplane in reducing through hand-to-mouth buying the amount of capital tied up in business inventory. The release of much of this capital for other purposes presents great possibilities to American business and, as President Cowie of the American Express has said, "commercial air transport is the logical delivery system of hand-to-mouth buying." Somewhat different, but illustrating again the importance of time saved, is the present flying of fresh fish from the Atlantic Seaboard to Chicago, and from the Gulf of Mexico to Brownsville, Texas, the fish being packed there for shipment to northern cities. And in passenger transport, future possibilities are clearly indicated by use of both scheduled air transports and private planes in the conduct of personal, professional, and especially business affairs throughout the country. Mr. Leighton W. Rogers, Chief of Foreign and Domestic Commerce, in an article in Airway Age, has given some vivid illus-

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19 *Aviation*, January, 1931, pp. 19 and 54.
trations of the significance of the airplane as a time saver in passenger transport. Although not drawn from the United States, these illustrations indicate the tremendous future that lies ahead for the airplane. In one case, a plane was being used in place of mules to reach a potentially productive mine in a isolated section of the Andes, in another, a monoplane was replacing dogs in the Yukon. In South America the time saved was the difference between 6 hours and 3 weeks; in the Yukon, the difference in time was 12 days by sled and 1 hour and 45 minutes by plane.

But if the nature of the airplane clearly indicates the fact that speed will be its prime advantage, it also indicates the further fact that heavier-than-air craft will be primarily, as regards freight, carriers of the more valuable, less bulky goods and not to any great extent carriers of heavy, bulky commodities of low value. A brief analysis of the theory of flight will reveal the reason for this fact. It is a matter of common knowledge that when a body is moved through water, there is developed in the fluid a resistance to that movement. The same is true when an attempt is made to drive an object through the air—there is created by the air stream a very marked resistance to the movement of the object. This resistance to forward movement is known in aviation as the “Drag” and must be counteracted by a forward movement called “Thrust,” which is imparted by the motor-driven propeller. But in addition to this the airplane has the peculiar task of supporting itself against the pull of gravity, since it is in a fluid much lighter than itself. In order to provide for this, the main surface of the plane’s wing (or wings) is inclined to the direction of the air flow in such a way as to break this resistance force into two components, one acting in a direct line and the other at right angles to it and vertically. This latter component force is called the “Lift” and when the power exerted by it exceeds the downward force exerted by gravity the airplane rises. We shall return to these considerations again later, but the important point to note in the present
connection is that the lift, as well as the drag, is derived from the resistance offered by the air flow to the moving plane. This resistance depends upon the speed with which the airplane meets the air stream and therefore the greater the weight to be lifted, the more powerful the force required to drive the plane forward. Thus from its nature, the heavier-than-air craft requires great power per unit of weight moved, a fact which directly limits its ability to transport heavy, low value freight economically. One recent writer even questions, because of this fact, whether the airplane can compete successfully with other means of transport as a carrier of passengers, for he points out that "An automobile, for instance, can carry five persons satisfactorily with a power plant having a minimum of roughly 10 horsepower per passenger. An airplane of similar capacity, however, requires a minimum of about 60 horse-power per person for dependable performance."  

These theoretical considerations regarding the future part to be played by the airplane in the carriage of freight may be substantiated by referring to past and contemplated developments in freight-carrying by plane. At the present time, the articles carried by plane include fruits, vegetables, fresh fish, cut flowers, dry goods, millinery, machine parts, some heavy pieces of machinery, newspapers, jewelry, advertising cuts and mats, motion picture films, securities, and currency and bullion. It will be noticed that all of these different articles, except the pieces of heavy machinery, possess the characteristics outlined above. There will undoubtedly be some carriage of heavy freight by airplane where time in transit is, for various reasons, at a great premium, but it seems apparent that the airplane will handle for the most part light, valuable, less bulky commodities. One writer quotes the President of the Curtiss-Wright Corporation

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22 For a clear explanation of the elementary principles, underlying the theory of flight, see Woolley and Hill, *Airplane Transportation*, Hollywood, 1929, Chap. 7.  
to the effect that "Anything that is light and valuable, such as Paris gowns and hats, or that is small and valuable, such as jewelry, makes ideal air express mat-
ter."24 A reader of Aviation, in writing to the Editor on the revenue possibilities of air express and air freight, declares that "the express and freight must have con-
siderable value" and that "low value express and freight would be out of the question."25 He mentions, however, that the airplane can handle hundreds of high value articles. And finally, it is reported that the articles to be handled by a nation-wide freight service will be "all goods of a precious, or luxurious nature, or goods upon which time in transit is at a premium, such as jewels, orchids, violets, baby chicks, stocks and bonds, style merchandise, and many other such articles."26

From the foregoing considerations it appears that the future of the airplane as a mode of transportation lies in the carriage of passengers and of certain types of freight for which the element of time saved is of value. There is a further question, however, which arises at this point, the significance of which it would be impos-
sible to over-emphasize. And that is, can the airplane provide these services for which it is peculiarly fitted, economically and in competition with other forms of transport? In the answer to this is to be found the key to aviation's future. Time saved is of distinct value in many instances but there is an upper limit to that value. It is clear that, allowing for the speed differential, the cost of air transport must be reasonably low and must compare favorably with the cost of other types of transport if the airplane is to assume a significant part in the aggregate transport system of the future. More-
over, besides cost there is the added question of safety. The airplane must be a reasonably safe agency of transport. This factor of safety, while of great import-

26 Aviation, March 22, 1930, p. 624. This company is to begin operations sometime during 1931.
ance in transport, is especially significant as concerns the future of private flying, for, as one writer has expressed it, "The airplane must be made safer and easier to fly before it will be available to the private owner in great quantities." 27 With these facts in mind, the National Advisory Committee for Aeronautics in its latest report concludes that "In the last analysis, the future of aviation may be said to depend upon the degree to which safety is increased and costs are decreased." 28

It is thus directly pertinent to our study of the future of air transportation to inquire into the possibilities first, of increasing the safety of the airplane, and second, of decreasing its cost. Very clearly, such inquiries must necessarily be based upon a consideration of present developments and present trends as they seem to presage the future.

The problem of safety in flight may profitably be viewed from two different angles. There is, first, the question of increasing the aerodynamic safety of the airplane itself, and, second, the question of developing to a greater degree of efficiency various aids to safe flight. This latter problem derives its significance mainly from the fact that at the present time unfavorable weather conditions, especially fog, are among the chief obstacles to safety and reliability in air transportation. Because of this fact, a great deal of effort is being devoted to a study of factors which will reduce, if not eliminate, such hazards. Recent progress in this connection includes developments in "blind" and mechanical flying. Mechanical flying is flying conducted by a mechanical, or robot, pilot, "an instrument that" according to one writer, 29 "will fly a plane safely and accurately in any kind of weather, whether during the day or night." "Blind" flying is flying in which the pilot relies entirely upon his


instruments. One of the clearly essential instruments for this is an altitude indicator. Until recently, however, altimeters were unsatisfactory because they indicated only the height of the plane above sea level and not, what is the important thing, the height of the plane above the terrain directly below it. Many accidents have in the past resulted from this fact. At present, there is being developed an altitude indicator which will correct for this defect. Sound waves are transmitted to the earth and reflected back to the plane and the time required, divided by two and multiplied by the distance traveled by sound per second, gives the desired information as to the height of the plane above the land over which it is flying.

Very significant also from the standpoint of safety are the directional aids provided by the Department of Commerce. The government through this department supplies navigational lights over thousands of miles of airways for night flying; 30 it is installing directive radio beacons which deliver, through a code letter system, information to the pilot regarding his position with reference to his true course; and it has inaugurated a low-frequency radio-telephone broadcast service to advise pilots regarding landing and weather conditions along their routes. 31 There are now thirty-five of these radio stations for the dissemination of weather information, and when the total number proposed are built, there will be no area in any part of the United States where there is flying that will not be served with proper radio service. 32 More than this, many air transport operators are in addition installing high-frequency, two-way radio-telephony for communication between planes and air

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30 The Aircraft Yearbook for 1931 (p. 541) gives 13,459 as the lighted mileage in 1930 with 2,078 more miles under construction. For a complete account of the services rendered air transportation in the lighting of airways, see F. C. Hingsburg, "Air Navigation Facilities," Aviation, August, 1930, p. 69.

31 For a discussion of these last two developments, see J. H. Dellinger and H. Diamond, "Radio Developments Applied to Aircraft," A. S. M. E. Trans., AER-51-11, p. 57 (1929).

32 A. S. M. E. Trans., AER-53-1, p. 16 (1931). The frequency used is 278 kilocycles.
bases, and the Federal Radio Commission has reserved 64 channels for this development. According to the author of this paper to which reference is here made (footnote 33), the inter-use of these two systems of weather reporting should "measurably increase the safety of operation." While these developments have been made primarily for the purpose of increasing safety in scheduled commercial transport, they are also available for the private flyer.

While a great deal of effort is being expended in the development of aids to safe flight, so research is being pressed with the aim of improving the safety of the airplane itself. It would be impossible within the necessary limits of this paper to set forth in any detail the progress in this connection that has been achieved up to the present time, but enough may be presented to indicate in general the future possibilities of safety in flight.

According to the National Advisory Committee "accident reports still indicate that the majority of accidents are connected with forced or bad landings and the tendency of airplanes to spin in the very high altitude where they should be most easily controlled. . . . One of the greatest fields for increasing safety is, therefore, the improvement in stability and control throughout the entire possible [speed] range and the reduction of the space required for landing." In view of these facts, the committee is devoting a large part of the work of the laboratories at Langley Field to a consideration of spinning, stability, controllability, ice formation on aircraft, and landing. Several universities, the Bureau of Standards, and the transport companies are carrying on investigations along similar lines and the United States Weather Bureau is engaged in the study of ice formation as it affects the safety of plane operation.

33 See citation in footnote 5, supra. The channels are in the 1600-1650 kilocycle band.
35 For information on the progress so far achieved in all of these investigations, see the Fifteenth and Sixteenth Annual Reports of the National Advisory Committee.
The problems of ice formation and landing may be mentioned briefly as indicative of this work which is being carried on in an attempt to increase the airplane's aerodynamic safety. The formation of ice on aircraft presents an element of danger in that it results "not only in an increase in weight of the airplane but also in the deformation of the aerodynamic shapes upon which the lift and drag depend."\textsuperscript{36} Investigations of this phenomenon have been conducted both by the National Advisory Committee for Aeronautics in a refrigerated wind tunnel and by the Weather Bureau in cooperation with National Air Transport (Inc.). The information obtained from these studies indicates that "the temperatures most favorable for the formation of ice are between 0 and —2 or —3 degrees Centigrade [i. e., a little below the freezing point], and that though ice does form in lower temperatures it is simply rime and is not heavy enough to be dangerous."\textsuperscript{37}

Perhaps the most significant development as yet for the prevention of ice formation is that of a rubber "overshoe," devised by Dr. W. C. Geer in cooperation with the Guggenheim Fund. Tested by the National Advisory Committee, it "worked quite well in the tunnel, causing the ice to break off as rapidly as formed."\textsuperscript{38} The landing of a plane also involves an element of danger, for the present high landing speeds of airplanes necessitate, for safe landing, larger areas than are sometimes available. Most planes at present land at 55 to 60 miles per hour and heavily-loaded transport planes have landing speeds of around 70 miles per hour.\textsuperscript{39} The most important progress yet achieved toward a solution of the landing problem has been the development of wheel brakes which are now to be found on many planes.

\textsuperscript{36} Fifteenth Annual Report, National Advisory Committee for Aeronautics, 1929, p. 26.
\textsuperscript{37} Sixteenth Annual Report, National Advisory Committee for Aeronautics, 1930, p. 44.
\textsuperscript{38} Sixteenth Annual Report, National Advisory Committee for Aeronautics, 1930, p. 21.
\textsuperscript{39} A. S. M. E. Trans., AER-51-14, p. 78 (1929).
A consideration of the possibilities of increasing the aerodynamic safety of the airplane would be incomplete, however, if it failed to include a brief examination of two recent developments, the future significance of which will doubtless be great. These developments are the Autogiro and the Diesel engine. The Autogiro is a type of heavier-than-air craft devised by Juan de la Cierva, which secures its lift through the use of rotating wings. There can be no question but that the Autogiro from its very nature possesses inherent safety. According to one writer: "the aviation industry has been waiting for a machine which from the standpoint of safety would not represent about 90 per cent piloting skill and 10 per cent stable aerodynamic design. . . . In the Autogiro we have been given such a machine. In fact, one might say that the element of personal safety is governed, in the Autogiro, in the ratio of about 10 per cent piloting skill and 90 per cent inherent aerodynamic stability. The safety of the rotating-wing craft is about as high as can be hoped for in any field of mechanical transport."\(^{40}\)

The Diesel engine, the underlying principle of which was conceived by a German, Dr. Rudolph Diesel, has been modified and developed as a prime mover for aircraft. This development of the Diesel engine for airplane use has, in the United States, been carried on primarily by the Packard Motor Car Company. Because of the undoubted significance of this development of the oil engine, it will be well to consider the Diesel principle as it is applied in the aircraft engine. According to the designer of the Packard-Diesel, the late Captain L. M. Woolson, the "real point of departure" between the gasoline and the Diesel engine is "the ignition system involved."\(^{41}\) That is, while the gasoline engine depends upon an electric spark to fire its charge, the oil engine depends upon the great heat of high compression to ignite the charge of fuel. Thus in the Diesel engine the entire

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\(^{40}\) Thomas Carroll, "Relative Flight Safety of the Autogiro," *Aero Digest*, December, 1930, p. 72.

ignition system is eliminated. The heat utilized to fire the fuel is obtained in this wise; whereas, in the gasoline engine vapor and air are introduced into the cylinders, in the Diesel only pure air is admitted. This air is compressed to such an extent that its temperature increases far above the spontaneous ignition temperature of the fuel used. "Accordingly," to quote again from Captain Woolson's article, "when the fuel is injected in a highly atomized condition . . . the fuel burns as it comes in contact with the highly heated air and the greatly increased pressures resulting from the tremendous increase in temperature brought about by this combustion, act on the piston drive of the engine the same as in the case of the gasoline engine."42 And finally, while the carburetor engine employs a fuel of high volatility and ease of ignition, "the fact that the air supply of a Diesel engine is compressed and its temperature raised to such a high degree permits the use of liquid fuels with a very high ignition temperature. . . ."43

Several important considerations flow from the nature of the Diesel engine, some of which we will have occasion to touch upon later, but the significant fact in the present connection is the reduction in fire hazard which it makes possible. In any delineation of the advantages of the oil engine in aircraft, the element of diminished fire risk plays, quite correctly, an important rôle.44 This increased safety is obtained as the result of the ability to employ as fuel, not the highly volatile and inflammable gasoline which ignites easily at ordinary temperatures, but rather oils which have very low volatility and which will ignite only at relatively high temperatures. More than this, these heavy oils will actually extinguish a small fire if allowed to flow upon it. As stated in a paper delivered before the American

44 See, for instance, A. S. M. E. Trans., AER-50-11, p. 18 (1928), and AER-51-1, p. 1 (1929).
Society of Mechanical Engineers,\textsuperscript{45} "it has been shown in tests that fuel oil at ordinary temperatures cannot be made to ignite from sparks and small blazes, and that where an incipient fire is already started a quantity of fuel oil thrown upon it, as might be spilled from a crashed airplane's fuel tanks, will extinguish it." This last interesting fact is stressed by the Packard Company.\textsuperscript{46}

Having considered something of the possibilities of increasing the safety of the airplane, let us turn to an examination of the second factor upon which the future of aviation depends, the possibility of decreasing cost. Too much emphasis cannot be placed upon the significance of this factor, for, to a very great degree, the question of the place of aviation in the aggregate of transportation centers around the problem of air costs. The National Advisory Committee for Aeronautics has well expressed the importance of this in the following terms: "The great economic question confronting aeronautics at this time is, Are the people willing in increasing numbers to pay the present costs of air travel? We think not. Costs must be reduced to a competitive basis where after making allowance for time saved and for the inherent attractiveness of air travel the costs will be fairly comparable with other means of transportation."\textsuperscript{47} Thus the "great economic question confronting aeronautics" becomes this, Can costs be reduced? In seeking to answer this all-important question on the basis of present indications, it will be well to break down total airplane costs into three major divisions and to consider each separately. These three are: first cost, maintenance and depreciation, and operation. Bearing in mind always the fact that the problem is the same in each case, namely, that present expenses are too high and must be


\textsuperscript{46}The Packard-Diesel Aircraft Engine, a pamphlet of the Packard Motor Car Company.

\textsuperscript{47}Fifteenth Annual Report, National Advisory Committee for Aeronautics, 1929, p. 88.
diminished, let us examine for each of the three the possibilities of achieving such necessary diminution in cost.

The initial cost of heavier-than-air craft is disproportionately high in comparison with the first cost of a land or water craft of similar capacity. This high cost obtains in the case of both the aircraft engine and the plane structure proper, and for the same reasons. In the first place, as we have already seen, there is the impelling necessity in airplane construction of holding the total weight to a minimum. This follows, it will be recalled, from the fact that the lift is derived from the resistance offered to the plane by the air stream and that therefore the greater the weight to be lifted the greater the resistance that must be secured from high speeds which necessitate correspondingly great power. But furthermore, since there is this necessity for minimizing total weight, there is exceptional pressure on the designer of an airplane to keep the weight of the engine and structure down to a minimum, in order to make available as much useful load as possible. At the same time, materials of great strength are necessary in order to insure safety. Thus these twin requirements necessitate the utilization of light, strong materials, such as the alloys of aluminum, and materials of this nature are costly. In the second place, considerations of safety require extreme precision in the manufacture of both engine and structure, and the obtainment of such precision involves high labor cost. The inevitable result of high labor cost and high cost of raw materials is high total cost.

The problem of decreasing this high initial cost seems to center mainly about the possibility of realizing the advantages inherent in mass production. That the production of engines and planes on a large scale through the utilization of specialized machinery would reduce costs is unquestionable and is fully appreciated in the aviation industry. The substitution of machinery for hand labor in production has two major effects: it increases the fixed costs, such as interest and deprecia-
tion, and decreases the variable labor costs. Now if a small number of units are to be produced such a substitution of machinery for hand labor would increase the cost of each unit because the additional fixed charges would more than offset the saving in variable expenses. But if a large number of units are to be produced, then the saving in variable costs is greater than the increased fixed charges because these latter, fixed in total amount, are spread over so many units that the charge against each unit is relatively small. Thus suppose that the operation of a stamping machine in an airplane factory results in an increase of fixed costs of fifty dollars a day. Assume too that the reduction in the cost of skilled labor amounts to five dollars per unit. Clearly, if less than ten units are produced daily, unit costs are even greater than before; but if say thirty units are turned out each day, then a substantial reduction in unit cost is achieved.

The realization on the part of producers of the significance of this effect of quantity production on unit cost is indicated by present trends in both engine and structure construction. In the case of aircraft engines, the National Advisory Committee states that "To reduce the initial cost of the engine many of the smaller manufacturers are concentrating on one model, while one of the large manufacturers has a series of 5, 7, and 9 cylinder engines, which are built with the same bore and stroke, resulting in marked manufacturing and maintenance economics." The same indication is to be found in the case of airplane structures, where metal planes are finding favor for one thing because "they lend themselves more readily to mass production methods."

If, then, quantity production possesses the inherent advantage of low unit cost, why is there this problem of high initial cost in airplanes? The answer is that, while mass production can result in lowered first cost, the avia-

48 Fifteenth Annual Report, National Advisory Committee for Aeronautics, 1929, p. 86.
tion industry cannot achieve mass production because it cannot sell a large enough volume of planes at the present high prices that are necessitated by present high production costs. This peculiar paradox and its solution has been clearly set forth by the National Advisory Committee: "It is easy to see that reduction in unit costs can be accomplished by increase in volume, but volume cannot be satisfactorily increased with costs as they are. The answer is to improve the airplane . . . improve its aero-
dynamic efficiency and make it more controllable, especially at low speeds. All of these problems are included in the current research programs of the committee, and the efforts of all existing agencies, governmental and private, are coordinated in an organized effort to solve them." 50 The solution to this problem of high initial cost is thus, peculiarly enough, to increase the cost of producing an airplane in the present in order to make it cheaper in the future. How long it will take to improve the airplane until it can be sold in large numbers is indeed a difficult, if not impossible, question to answer, but one man interested in the industry has expressed the belief that mass production with the use of special machines involving heavy capital investment is a "thing of the future, probably ten years at least. . . ." 51

A brief examination of airplane depreciation and maintenance immediately reveals in this particular the same limitation on the development of the airplane as a mode of transport that we have found in considering initial cost. According to the authors of Airplane Trans-
portation, "The life of an airplane in transportation operations may be considered as approximately 2,000 hours, in about two years. That is, after about 2,000 hours of flying, reconditioning and maintenance costs usually become so great as to warrant re-equipment, while, at the present rate of development, at the end of

50 Fifteenth Annual Report, National Advisory Committee for Aeronautics, 1929, p. 88.
two years there are available proven advanced types which render the older models obsolete and uneconomic." It appears from this, then, that the present rate of depreciation common to airplanes is very high, a fact which with the high initial cost of equipment means high cost in producing transportation. Furthermore, it appears that this high rate of depreciation is the result of two factors: great physical wear and tear and a high degree of obsolescence. On the other hand, heavy maintenance costs flow primarily from considerations of safety and from the extreme wear and tear on both engine and structure. Airplane engines require frequent overhauls; airplane structures require frequent repair and adjustment; and the nature of both is such as to necessitate continual expert inspection. This maintenance work involves great cost, not only because of its magnitude, but also because only skilled airplane and airplane engine mechanics can, from the character of the work, be employed.

The search for an answer to the question in which we are primarily interested brings to our attention several facts which appear to be, at present, of significance. In the first place, the present high rate of obsolescence in airplanes and airplane engines is clearly the result of the newness of the aviation industry and, hence, as the industry gradually matures and settles down to an acceptance of certain major features of design, this factor should measurably decline in importance. In the second place, an examination of the general problem of excessive depreciation and maintenance costs indicates that the most promising possibilities at present for effecting a reduction in these costs lie, for the engine, in general improved construction and, for the structure, proper, in development in the use of metal as the structural material.

Improvements and refinement in airplane engine construction will operate to extend the period of useful

52 Woolley and Hill, Airplane Transportation, Hollywood, 1929, p. 159.
life and at the same time to reduce the costs of maintenance. A striking development in this connection has been the creation of the air-cooled engine. The air-cooled engine not only has from two to three times the life of the water-cooled engine but it is also much less costly to maintain, for, while about one mechanic-hour must be spent on the water-cooled engine for each flying hour, only one mechanic-hour is needed on the air-cooled engine for each four flying hours.\textsuperscript{53} Of late, improved construction of the air-cooled engine has resulted in maintenance economics through increasing the flying time between overhauls. Thus it has been stated that Wright J-5 motors are now run 275 hours before overhauling, according to the Thompson Aeronautical Corporation, and Wasp engines 500 hours, according to the Transcontinental Air Transport—Maddux Lines. \textsuperscript{54}

Without doubt, the most significant development from the standpoint of securing reductions in the depreciation and maintenance cost of airplane structures is the increasing use of metal in plane construction. This is clearly indicated by the statement made by the National Advisory Committee in its 1929 Report to the Congress to the effect that “Metal construction is coming gradually into use” and that “This will make airplanes stronger and safer, and by lengthening their lives and decreasing structural maintenance will operate to decrease flying costs.”\textsuperscript{55} Thus one writer sets forth as one advantage of metal airplanes the fact that “their life is longer,”\textsuperscript{56} and two English writers several years ago stated that while it was impossible at that early time to determine the effects of metal construction on maintenance charges, “everything points to a marked reduction being obtain-

\textsuperscript{53} Woolley and Hill, \textit{Airplane Transportation}, Hollywood, 1929, p. 292.

\textsuperscript{54} A. S. M. E. Trans., AER-52-18, pp. 131 and 135 (1930). Statements made by officials of these two organizations following presentation of prepared paper before the Society.


able in this respect.” There seems to be little doubt but that the high maintenance charges and rapid depreciation of previous years were to a great extent the result of constructing airplanes of wood and fabric, so that, as many aeronautical engineers believe, metal construction should tend to decrease such costs. However, all engineers do not agree on this, because of the difficulties of corrosion that are encountered with the use of metal. But the possibility of reducing these depreciation and maintenance costs, provided the difficulties of corrosion can be overcome, seems to be at hand with metal construction as is well illustrated by a statement of an official of Transcontinental Air Transport to the effect that his company has several Ford monoplanes with well over 2,000 hours of operation but that “unless crystallization or fatigue of the metal develops it is the writer’s opinion that these ships may give perfect service without major overhaul for some five to ten years.”

Some conception of the prevailing high level of operating costs may be gained from figures on commercial transport given in Aviation. It has been stated there that a fair average of operating costs for 1930 was about $0.90 to $1.40 per ton-mile and that during the year the purported costs of operating three-engined transports carrying from ten to fourteen passengers ranged from $0.30 to $1.75 a mile. It is significant to note that after mentioning these latter costs the writer goes on to say that “The one thing that is clear is that in practically all cases either an increase in rates or an increase in inherent operating efficiency of the equipment used is going to be required in order to wipe the red off the ledger.” Rates, however, cannot be increased appreci-

60 Aviation, October, 1930, p. 193.
61 Ibid, same page.
ably if commercial air transport is to compete with other modes of transportation, and we therefore see once again, looking at the problem from the standpoint of the commercial plane this time, that the future of aviation in the aggregate transportation system depends to a very great degree on the extent to which costs can be lowered. In considering this final question of the reduction of operating cost, two recent developments may be discussed as indices of the possibilities which appear to lie in the future.

The first of these developments is what may be called in general terms a systematic effort to reduce drag to a minimum. The National Advisory Committee for Aeronautics considers this to be one of the four major aero-dynamic problems demanding solution at the present time. The importance of this element of drag lies in the fact that the fuel consumed by an airplane over a given distance is proportional to the drag, while at the same time "The economy of fuel consumption of the engine is an important factor in the cost of operation." The National Advisory Committee considers the so-called "N. A. C. A. cowling" to be one of the most significant contributions yet made in this connection. In fact, in recognition of its importance, the committee was awarded in 1930 the Collier Trophy, a trophy awarded annually by the National Aeronautic Association "for the greatest achievement in Aviation in America, the value of which has been thoroughly demonstrated by actual use during the preceding year." This cowling, which the committee has developed, may be defined in general terms as a covering which is installed in connection with radial air-cooled engines in such a way as to entirely inclose them. It has, "by decreasing the air resistance of air-cooled engines, . . . the effect either of materially increasing the speed of the airplane or of decreasing fuel consumption." Although the increase in speed which it

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63 Ibid, same page.
64 Ibid, p. 2.
permits, an increase up to twenty miles per hour, is important in many cases, its effect in decreasing fuel consumption at a given speed is even more important. A table drawn from data presented in the two Technical Reports that have been published on the committee’s whole study of cowling will reveal the extent to which drag may be reduced through the use of complete cowling.

**TABLE II**

**Effect of Complete Cowling on Engine Drag**

<table>
<thead>
<tr>
<th>Body and cowling</th>
<th>Fuselage and engine drag, Pounds at 100 miles per hour</th>
<th>Reduction from uncowed engine, Pounds at 100 miles per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open cockpit fuselage, engine uncowed, No. 1</td>
<td>141</td>
<td>0</td>
</tr>
<tr>
<td>Cabin fuselage, engine uncowed, No. 4</td>
<td>125</td>
<td>0</td>
</tr>
<tr>
<td>Open cockpit, fuselage, no spinner, No. 2</td>
<td>136</td>
<td>5</td>
</tr>
<tr>
<td>Open cockpit fuselage, spinner, No. 3</td>
<td>132</td>
<td>9</td>
</tr>
<tr>
<td>Cabin fuselage, no spinner, original, No. 5</td>
<td>119</td>
<td>6</td>
</tr>
<tr>
<td>Cabin fuselage, spinner, original, No. 6</td>
<td>116</td>
<td>9</td>
</tr>
<tr>
<td>Open cockpit fuselage, complete cowling, No. 11</td>
<td>73</td>
<td>68</td>
</tr>
<tr>
<td>Cabin fuselage, complete cowling, modified to cool, No. 10</td>
<td>75</td>
<td>50</td>
</tr>
</tbody>
</table>

The outstanding feature of these drag tests is clearly the low drag obtained with the use of the complete cowlings, numbers 10 and 11. Numbers 2, 3, 5, and 6 represent conventional forms of cowling and it will be noticed that these “have but a very slight effect on the drag.”

After the conclusion of this first study of drag the committee states that “It now appears that the possibilities in this field are much greater than were anticipated when the original cowling investigation was started in

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the propeller research tunnel.”67 and there has therefore been initiated a general study of drag in all its forms, both direct, where it is due to exposed parts of the plane, and indirect, where it is the result of interference between various parts of the ship. Thus, as regards direct drag, a series of tests has recently been made of the drag of the engine, fuselage, landing gear, tail surfaces, open windows, etc., of a Fairchild cabin monoplane. “The largest single item of drag was that of the radial air-cooled engine. The landing gear also showed a high drag. The drags of the tail surfaces, turtle back, and open cabin windows were small.”68 Other recent tests have revealed that a rather high drag is occasioned by the position of the wheels below the wings and fuselage. These studies have led to some important developments in airplane construction. The realization that the landing gear is a cause of high drag has resulted in the design, and installation on many planes, of retractable landing gears, landing gears which can be drawn up into the fuselage while the ship is in flight. The use of fairings, or streamlined coverings, for wheels and tires in order to reduce the high drag of these parts is common now, such fairings being standard equipment on many designs, and one small plane, the Eaglerock Bullet, practically eliminates this resistance offered by the wheels by retracting the greater portion of them into the wing.69 In fact, the whole definite emphasis on streamlining, so apparent at the present time, is directly traceable to the appreciation on the part of aircraft builders of the importance of reducing this direct drag to a minimum.

The problem of the indirect drag caused by the inter-

ference between various parts of the plane, as for instance between wings and body and between propeller and body, is also engaging the attention of the committee, the "immediate problem" being "to discover the particular combinations which produce large adverse conditions and to find the most effective methods of eliminating the adverse effects." Tests are being conducted at the present time and possibilities for reducing this type of drag have already been found. At the same time the committee has before it the "general problem" of discovering the "general principles underlying the phenomenon so that it will be possible for the designer to predict the interference and to make use of favorable effects."

Significant also in connection with this effort to reduce resistance because of its unfavorable effect on operating costs is the trend toward the monoplane type of aircraft, a trend which the National Advisory Committee attributes to "an increasing appreciation by designers of the importance of large aspect ratio and low parasite drag. . . ." Table III has been prepared to show this tendency toward the monoplane.

**TABLE III**

**PRODUCTION OF CIVIL AIRCRAFT BY STRUCTURAL TYPE**

<table>
<thead>
<tr>
<th>Type of Plane</th>
<th>1928 Number</th>
<th>1929 Per cent of Total</th>
<th>1929 Number</th>
<th>1930 Per cent of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monoplane</td>
<td>1079</td>
<td>100</td>
<td>2060</td>
<td>40</td>
</tr>
<tr>
<td>Biplane</td>
<td>2422</td>
<td>69</td>
<td>3126</td>
<td>60</td>
</tr>
<tr>
<td>Total</td>
<td>3501</td>
<td>100</td>
<td>5186</td>
<td>100</td>
</tr>
</tbody>
</table>

It will be noticed that the biplane still predominates although there is a trend toward the one-wing ship. The small number of planes produced in 1930 is to be

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73 From data given in the *Aircraft Yearbook for 1931*, p. 496.
accounted for by the over-production of airplanes in 1929 and the general depression in business activity.

The second development that may be mentioned as indicating the future possibilities of reducing operating costs is one which we have already touched upon in another phase of this study. It is the recent introduction into aviation of the Diesel engine. The Diesel type of motor is a significant factor in reducing operating costs in the same way as is diminished drag—the result of each is to increase the economy of fuel consumption, an economy which is, as we have found, an important element in the total cost of operation. This increased fuel economy is secured by the Diesel engine in two different ways: through the use of cheap fuels and through a diminution in the amount of fuel consumed in a given distance. The Packard Motor Car Company emphasizes this two-fold economy of the oil engine in their statement that "The low fuel consumption inherent with the Diesel cycle, plus the lower cost of Diesel fuel, makes possible the operation of a four place cabin airplane at fuel cost of three-quarters of a cent a mile." 

The relative cheapness of the fuel required by a Diesel follows from the fact that, because of the high cylinder temperatures resulting from the compression of the air supply, liquid fuels of very high ignition temperatures can be utilized, "and it is these fuels which correspond more nearly to the crude petroleum as it issues from the well, which fact accounts for the much lower cost of the Diesel fuel as compared with the highly refined gasoline needed for aircraft engines." Two writers who have made a very complete comparison between the gasoline and oil engine consider fuel oil as

75 The Packard-Diesel Aircraft Engine, a pamphlet of the Packard Motor Car Company.
costing about one-fourth as much as aviation gasoline. Although other writers do not seem to agree with this estimate of the spread in the prices of the two kinds of fuel, believing it to favor the Diesel engine slightly, there is no question but that the fuel used by the Diesel engine is considerably cheaper than that utilized by the carburetor engine.

Lower fuel consumption per given operation is the result of another feature of the Diesel engine, its use of the two-stroke cycle. In the gasoline engine the fact that air and gasoline vapor are introduced into the cylinder together requires the employment of separate inlet and exhaust valves in order to prevent loss of fuel through its mixing with the exhaust gases. But in the Diesel engine, since only pure air is admitted, there is needed only one valve for both intake and exhaust. This results not only in simplicity of construction but also in a saving in the amount of fuel used. This saving in fuel consumption which the oil engine effects over the carburetor engine is clearly shown in Table IV, a table drawn up from curves for fuel consumption given in the study of the gasoline and oil engine to which reference was made above.

**TABLE IV**

<table>
<thead>
<tr>
<th>Type of Engine and Amount of Power</th>
<th>Fuel consumption in pounds per horsepower per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60%</td>
</tr>
<tr>
<td>Gasoline engine, 200 horsepower</td>
<td>0.56</td>
</tr>
<tr>
<td>Oil engine, 200 horsepower</td>
<td>0.42</td>
</tr>
<tr>
<td>Gasoline engine, 2000 horsepower</td>
<td>0.51</td>
</tr>
<tr>
<td>Oil engine, 2000 horsepower</td>
<td>0.40</td>
</tr>
</tbody>
</table>


The writers of this excellent paper have considered engines "at the opposite ends of the size scale" and have based their curves for fuel consumption "on factors believed to be reasonable." Notice that for all the various loads, from 60 per cent of full load to 100 per cent of full load, the two oil engines are superior to the two gasoline engines of similar capacity in point of fuel economy. Note also that the oil engines can handle a 25 per cent overload on less fuel than the carburetor engines of similar horsepower require for the carrying of normal load.

The combined effect on the economy of fuel consumption of these two factors of lower specific fuel consumption per given operation and lower cost of fuel per given quantity was strikingly illustrated by the flight in May, 1929, of a plane powered with a Packard-Diesel from Detroit to Langley Field, Virginia, the site of the laboratories of the National Advisory Committee. The fuel cost for the trip was $4.68, while the cost of sufficient gasoline to make a similar flight with a carburetor engine was estimated at the time at about $27. Although it is difficult to judge the future, it appears from the considerations regarding the oil engine which we have noted in this study that this type of aircraft power plant will play an important rôle in the future of heavier-than-air craft. Thus one recent writer, after noting among other advantages of the Diesel engine "reduced fire hazard" and "better fuel economy," states that "The author's belief is that for transport work in the not too distant future the Diesel engine will rule supreme." The great disadvantage of the oil engine for airplane use has always been in the high cylinder pressures which result from the great compression of the injected air. These cylinder pressures, considerably greater than those encountered in the gasoline

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80 Ibid, pp. 33 and 34.
engine, necessitate correspondingly greater strength in the engine and hence an increase in its weight. Recent developments, however, have greatly diminished the spread between the weight of a gasoline and an oil engine of similar capacity, so that at the present time the Diesel engine weighs only about ten per cent more than a corresponding carburetor engine.\textsuperscript{83} This great accomplishment in reducing the weight of the oil engine is illustrated by the fact that whereas a few years ago a so-called light weight Diesel weighed around 25 pounds per horsepower,\textsuperscript{84} today the Packard-Diesel weighs only 2.31 pounds per horsepower.\textsuperscript{85} And, moreover, for flights of any considerable distance, the lower fuel consumption of the Diesel, which permits of the carriage of lesser amounts of fuel, offsets this disadvantage of somewhat greater weight in the engine proper.\textsuperscript{86}

\textsuperscript{85} \textit{The Packard-Diesel Aircraft Engine}, a pamphlet of the Packard Motor Car Company.
\textsuperscript{86} Robert J. Nebesar, "The Theory of Long-Distance Flight," \textit{A. S. M. E. Trans.}, AER-50-21, p. 21 (1928). This is a paper showing that for long-distance flight minimum consumption of fuel for a given distance is the important thing and not the weight of the engine.
APPENDIX

a. Figures from the Bureau of Railway Economics, *A Review of Railway Operations in 1930*, p. 8. The figure for ton-mileage does not include mail or express handled by the Class I roads. Figures for 1930.

b. No information is available on the number of passengers carried in coastwise transport nor on the passenger-mileage involved. Information on coastwise freight movements from the *Annual Report of the Chief of Engineers, U. S. Army, 1930, Part 2*, p. 1. The figure given is in short tons of 2,000 pounds and is for the year 1929.

c. Figures on both number of passengers and ton-mileage of freight from the *Annual Report of the Chief of Engineers, U. S. Army, 1930, Part 2*. See p. 3 for ton-miles and p. 31 for number of passengers. Figures for 1929.

d. Information on the number of passengers from Meador Wright, *Interurban Electric Railways*, Chart XI. This was a thesis submitted in 1930 to the Faculty of Political Science, Columbia University in partial fulfillment of the requirements for the Master of Arts degree. The figure given is for 1927. Information on ton-mileage of freight from the Bureau of Railway Economics, *An Economic Survey of Inland Waterway Transportation in the United States, 1930*, p. 210. This figure is for the year 1928 and is an estimate of the Bureau.

e. The figures for commercial motor transport operations are estimates determined in the following way. In the case of passengers, there were 497,000,000 inter-city passengers transported by common carrier buses in 1930.\(^1\) Statistics regarding average ride by bus determined by the Interstate Commerce Commission and by the Bureau of Public Roads seem to indicate that 20 miles is about the average.\(^2\) These two amounts when multiplied together give the figure in the table, a figure that is for 1930. In the case of freight, an estimate was made by applying to the 1925 motor truck traffic estimate of H. R. Trumbower, Economist, U. S. Bureau of Public Roads, the percentage of increase in the number of trucks from 1925 to 1930. Motor truck registration in 1925, 3,114,000; in 1930, 3,413,725.\(^3\) On the basis of these calculations the total 1930 ton-miles handled by all classes of trucks were 11,303,600,000. This figure is probably low because it does not take into consideration the

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\(^1\) *Bus Facts for 1930*, National Association of Motor Bus Operators, p. 5

\(^2\) See 140 I. C. C. 699, figures produced in the course of the Commission's 1926 investigation of motor transport.

\(^3\) *Automotive Industries*, February 28, 1931, p. 292.
fact that the average truck haul has increased and probably also the amount carried by each truck, but it seems to be as accurate as can be secured. Of the total number of trucks, some are engaged in commercial, for hire, transport; the others are owner-operated trucks engaged in private trucking. The estimate usually employed as representing the proportion of commercial and of private trucking is: private, 82 per cent; commercial, 18 per cent. Using these percentages, the figure on commercial trucking is secured as is also the figure for private trucking. These figures are for 1930.

The figures for private motor transport operations are also necessarily estimates. The way in which there was derived the figure for ton-mileage of freight is indicated above in the case of passenger traffic, the estimate was made in this way. There are 23,251,050 private passenger cars in the U. S. It seems reasonable to assume that on the average around 20 per cent are running daily in interurban traffic. This gives approximately 4,650,000 cars moving every day. Studies by the Bureau of Public Roads, U. S. Department of Agriculture, afford information as to the average number of passengers per car and the average mileage per trip. Thus:

<table>
<thead>
<tr>
<th>Average Passengers Per Car</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Connecticut</td>
<td>2.71</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>2.80</td>
</tr>
<tr>
<td>Ohio</td>
<td>2.20</td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>2.60</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Average Mileage Per Trip</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>38</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>34</td>
</tr>
<tr>
<td>Ohio</td>
<td>31</td>
</tr>
<tr>
<td>Vermont</td>
<td></td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>35</strong></td>
</tr>
</tbody>
</table>

Then taking 2.60 as the average number of passengers per car gives a total of 4,412,850,000 passengers carried during the course of the entire year. Multiplying this last figure by the average distance traveled per trip gives the total passenger-mileage. These figures for private motor transport are also for 1930.

f. No passengers are carried on the inland waterways. The figure

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for ton-mileage secured from the *Annual Report of the Chief of Engineers, U. S. Army, 1930, Part 2*, p. 3. The figure given there is for 1929.

g. Pipe line transport is clearly not concerned with the carriage of passengers. For crude oil, the figure given in the table is an estimate based in turn on an estimate of the Bureau of Railway Economics give in *An Economic Survey of Inland Transportation in the United States*, 1930, p. 210. According to the Bureau, for 1928, "Pipe-line traffic, if reduced to ton-miles, would probably exceed 30 billions." The increase in the volume of pipe-line traffic in 1929 over 1928 was approximately ten per cent.\(^7\) Assuming about this same increase in 1930 over 1929 gives as the 1930 figure some 35,000,000,000 ton-miles.

Natural gas produced in the United States in 1929 amounted to 1,860 billion cubic feet.\(^8\) On the average, one cubic foot of natural gas contains 855 British thermal units of heat.\(^9\) Thus the total produced natural gas, practically all of which is moved by pipe line, supplied 1,590,300 billion British thermal units. Taking 26,200,000 as the average number of British thermal units per pound of coal\(^10\) gives 60,700,000 tons of coal theoretically displaced by the use of gas.

There are no figures available as to the amount of gasoline moved by pipe line, but it is certain that the amount is small. This mode of transport is a very new development, only one pipe line, that of the Standard Oil Company of Pennsylvania from Bayonne, New Jersey, to the Ohio River near Pittsburgh, having been in operation during 1930.\(^11\) No information is available regarding movements through this line, but they were of necessity relatively insignificant. The importance of gasoline transportation by pipe line is not to be gaged from this, however. It is a new thing in transport, scarcely out of its experimental stage. Certain technical difficulties involved in such movement, as for example the danger of leakage, have only recently been overcome, so that the practicality of the method has only been established a short time. Developments up to the present time seem to indicate a very significant future for this mode of transport.

\(^8\) *Statistical Abstract of the United States, 1930*, p. 751.
\(^10\) This is the figure used by the Bureau of Mines in calculating coal equivalents.
\(^11\) Information as to the present status of pipe line movement of gasoline from the American Petroleum Institute, 250 Park Avenue, New York.
h. Figures for intercoastal transport were estimated on the basis of information published by the United States Shipping Board. With regard to passengers, for the fiscal year ended June 30, 1930, westbound passenger traffic totaled 11,252; eastbound 9,763.\textsuperscript{12} No data is available as to average distance traveled per passenger, but from an inspection of the figures given by the Shipping Board such an average can be determined roughly on the basis of the major movements in intercoastal traffic, which were from New York to Los Angeles and San Francisco and vice versa. Thus the average distance may be taken as the distance from New York to a point between Los Angeles and San Francisco, or 5,850 miles. This figure is used because traffic between Los Angeles and New York and New York and Los Angeles was heavier than between San Francisco and New York and New York and San Francisco. Total number of passengers, 21,015, multiplied by the average distance, 5,850, gives the figure in the table.

For the fiscal year ended June 30, 1930, westbound freight from Atlantic and Gulf ports amounted to 2,934,180 cargo tons; eastbound freight from Pacific ports to 7,191,800 cargo tons. The total, after reducing figures from cargo tons of 2,240 pounds to short tons of 2,000 pounds, amounted to 11,341,098 tons.\textsuperscript{13} Information as to average haul is not available, but an estimate can be made on the basis of the major movements which were from the North Atlantic ports to Los Angeles and San Francisco. Thus the average haul may be taken as approximately the distance from New York to Los Angeles, or 5,677 miles. Multiplying the total tons by the average haul gives total ton-mileage. It must be remembered that the circuitous route via the Canal swells these figures for passenger- and ton-miles. Figures for the fiscal year 1929-1930.

i. Hydroelectric power produced in 1929 totaled 34,629,000,000 kilowatt-hours. During the same year, the average amount of coal consumed in producing one kilowatt-hour was 1.69 pounds.\textsuperscript{14} Thus if this same amount of electrical energy had been produced from coal, it would have required 29,261,505 tons of that fuel. Hydroelectric-power transmission has clearly no relation to passenger carriage. The figure is for 1929.\textsuperscript{15}

j. Figure for commercial air passenger transport from Aviation, March, 1931, p. 175. The figure for private passenger flying


\textsuperscript{13} U. S. Shipping Board, Bureau of Research, United States Water Borne Intercoastal Traffic, Report B. R. 317.

\textsuperscript{14} Statistical Abstract of the United States, 1930, p. 367.

\textsuperscript{15} Ibid, same page.