Suspended Monorail System

of

Rapid Transit

Atlantic Suspended Monorail Corporation

67 WALL STREET, NEW YORK

Presentation

of

SUSPENDED MONORAIL SYSTEM *of* RAPID TRANSIT

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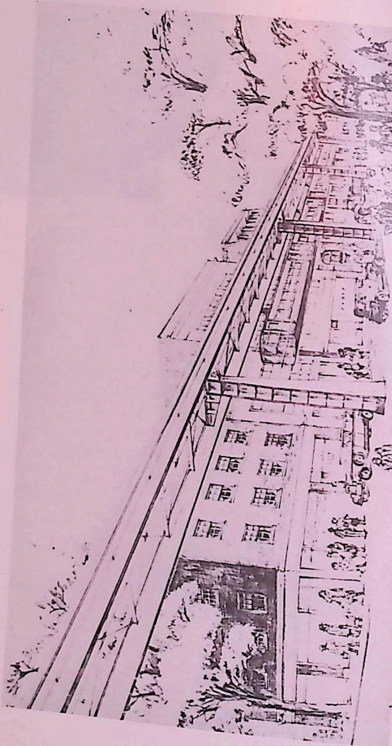


SUSPENDED MONORAIL SYSTEM OF RAPID TRANSIT

The Program

"Possible Use of Suspended Monorail in Undeveloped Sections of Queens"

HON. GEORGE U. HARVEY
President of Borough of Queens

HON. JOHN J. HALLERAN
Commissioner of Public Works, Borough of Queens

"Suspended Monorail—General Aspects"

FRANK S. LYON
President, Atlantic Suspended Monorail Corp.

"Suspended Monorail—Economic and Engineering Features"

GILBERT D. FISH
Consulting Engineer—Authority on structures and pioneer in arc-welded construction

Excerpts from notice of meeting:

"In 1841 John Willis Griffiths exhibited a model of a clipper ship at The American Institute . . . the first public showing of this radical departure from accepted standards of ship construction.

"True to tradition, The American Institute will sponsor the first public discussion of Suspended Monorail . . . a radical departure from accepted standards of rapid transit."

POSSIBLE USE OF SUSPENDED MONORAIL IN UNDEVELOPED SECTIONS OF QUEENS

By

HON. GEORGE U. HARVEY
President, Borough of Queens

THE possible use of the suspended monorail system of transit in the undeveloped areas of the Borough of Queens is a subject exceedingly difficult for even a technically-minded man to describe in detail. In attempting to set forth some of the possibilities of the suspended monorail as applied to the transit problems of the Borough, I feel that I am undeservedly assuming the robes of a prophet, for this revolutionary mode of travel is certain of public acceptance. Its potentialities as a means of serving the built-up sections of the Borough of Queens and of developing the wide areas yet to be populated are so varied that I feel that I am unequipped to properly discuss them in detail.

However, I fully understand the need of a new and inexpensive form of safe transportation in Queens as will anyone knowing the background of the Borough. Not so very long ago, the Queens Planning Commission presented a report which contained plans and recommendations for the orderly and scientific development of Queens. The Commission's members clearly envisioned the great Borough of the future and in detail recommended the steps that will have to be taken to solve the problems and avoid the mistakes of progress.

Since the presentation of this initial report, the Planning Commission has added a new chapter in recommending to the Board of Estimate and the Board of Transportation the suspended monorail as a possible means of meeting the great transit needs of the Borough.

Perhaps to say that Queens is on the dawn of a new era is to express the possibilities of tomorrow too tritely. Better to state, in terms clearly understood in this air-minded age, we are getting ready for a take-off on a flight of progress. Before us lie years that will witness a great development. Regardless of plans, reports or recommendations, this development is certain to come. Whether it will be haphazard or orderly depends on how we plan now. Will we grow crookedly and carelessly or as a great community providing for the comfort and convenience of future generations, allowing wide margins for wave after wave of expansion, providing broad highways for the armies of progress?

The Planning Commission's report is a sincere presentation of a solution of the problems confronting an adolescent community about to step forth in the habiliments of manhood. It is sound advice to a husky, vigorous and virile but youthful child of the City of New York about to take its place among the great municipalities of the country.

I have said that the members of the Planning Commission have clearly envisioned the great Borough of the future. I should amend that. The Commissioners have a deep appreciation, a sensitive understanding, a practical anticipation of the needs of the future, but I do not think there is one among them who can look down the vista of the years to come and discern a realistic picture of the great Empire Borough that will build up its monuments of steel and stone on the foundation of our own time.

In fancy we are prone to envision new sky-lines in Queens, gigantic towers of commerce reaching temple-like toward the skies; to see beautiful mirages of broad tree-lined boulevards, expansive express highways of stupendous steel structures, spanning our bays and rivers, of perfectly laid out residential parks, of recreational centers landscaped like Roman gardens, all merging into an amazingly pleasant background of exquisite dimensions and proportions.

Is that a dream or a practical vision? Is it a prophesy or a guess? Those of us who have spent more than a few years on this old mortal coil have witnessed astounding developments and changes. In the light of what has come to pass since I first began to observe the essential things of life, I think it is safe to say that all our castle-building will fall far short of the actualities of the future. Mechanical developments of our age —the automobile, the airplane, radio, television and now the suspended monorail—are indications of how little we can know of what the future really holds in store.

It is better to consider the past and to compare it with the present and then by relativity attempt to gauge the future.

In 1910, the population of Queens was 284,000 persons. To-day, we have close to 1,110,000 people living in this Borough. That is an increase of more than 800,000. In the past few years, Queens has been increasing its population at the rate of over 100,000 annually. Does not this give some assurance of the future? We have the evidence that Queens is the fastest growing Borough in the City of New York. We know that within a few years our population will grow beyond that of Manhattan and perhaps of all other Boroughs combined.

But before we begin to congratulate ourselves, let us seriously consider the duty that this growth imposes upon us. It is an awesome responsibility. We owe it to the teeming thousands, to the millions who are to crowd what are now the wide open spaces of Queens, who are to fill the homes yet to be built by the hands yet unborn—we owe these children of the future a duty to plan and to provide for an orderly, sane and reasonable course of development.

The Borough of Queens has the greatest potentialities of any community in the United States. With its 70,321 acres, it has the largest in area of the five Boroughs of the City of New York. Its geographical location gives it a strategic position with respect to three of its sister Boroughs. Its physical advantages are varied. Queens has 196 miles of shorefront, an ocean, sound, river, and Jamaica Bay, making it a great natural shipping center. Part of its terrain offers natural airport facilities. Its rugged contour on the north offers idealistic and natural park sites. Its adjacency to Manhattan and Brooklyn and its nearness to the heart of the world's business center makes it attractive to industry.

There is no rule by which we can properly measure our potential growth. There is no formula that we may follow in laying down a plan or design, but plan we must and try as consistently as possible to chart our development.

What the Planning Commission, with its eyes to the future, recommends is simply this—that we construct a system of modern highways in keeping with present and future traffic requirements; that we prepare for the future with intelligently laid out transit lines; that Queens and the other Boroughs of the City of New York be wedded in bonds of traffic communication, connecting links such as vehicular tunnels and bridges; that parks be acquired where land is inexpensive, at the present time, so as to provide recreational facilities when the municipality grows and expands; that harbors and airports be laid out and charted for the shipping needs of the future so that, on the whole, this community five years, ten years, twenty years hence may continue to grow without disorder, healthfully, wholesomely and robustly, suffering from no mistakes made now.

I believe that the public fully realizes and appreciates the purpose and spirit which has imbued the members of the Queens Planning Commission. I know that the men and women who make up the great body of homeowners will support the extremely practical policy of building for the future; of safeguarding the generations of the future from such mistakes as were made by the generations of the past. Queens is destined to be perhaps the greatest Municipal unit in America, but its future must be safeguarded and nurtured. The steps of this great but toddling child must be guided in paths of safety and reason. The visions of to-day may be the realities of to-

morrow but I feel that even the most optimistic and enthusiastic visionary portrait of the future will be a colorless and shapeless design when compared to the actual structure that our children's children will call Queens.

Against this background of physical resources, of advantages of location, of problems of development, of plans, hopes and predictions we may consider the monorail with a better appreciation of its possibilities.

In all my studies of the monorail, I have been guided by the reports of the Planning Commission, which, through its committee on Transit, has investigated this revolutionary system of transportation very thoroughly.

In considering the problem of serving the great area of the Borough, I, naturally, thought of the monorail as the possible answer to our problems. I read of its high degree of safety, its low cost of operation, its low cost of construction and of its other virtues. After some study, I recommended the suspended monorail as a subject for study by the Commission. The investigation that followed was intensive. No detail was overlooked. Under the chairmanship of Mr. L. A. Coleman, the Transit Committee interviewed railroad engineers, transit experts, civil engineers and other technical men qualified to pass judgment on a project of this kind.

As to the potentialities of the monorail as a means of quickly giving needed transit facilities to those sections of the Borough without proper forms of transportation, I was already fully informed. What I wished to know was whether the suspended monorail would be both practical and safe. I am glad to say that the answer contained in Mr. Coleman's report fully justified my interest.

Mr. Coleman and his associates interviewed officials of the Pennsylvania Railroad, including Mr. Crowell, Assistant to the Chief Engineer, and were advised that the Pennsylvania Railroad had investigated and reviewed specifications, plans and drawings prepared by engineers of the Atlantic Suspended Monorail Corporation, as well as data from the Westinghouse Electric and Manufacturing Company and the Osgood Bradley Car Company.

The Planning Commission's Transit Committee, in addition to its report on the practicability, economy, safety and speed of the suspended monorail, expressed the unanimous opinion that the Whitestone, College Point branch of the Long Island Railroad would be an ideal right-of-way for the first installation of the new overhead system. In fact, the Long Island Railroad Company has offered to turn over the right-of-way of the Whitestone branch to the City for rapid transit purposes and if such offer is accepted, we will propose that a monorail be constructed there. The committee also ascertained that the construction of such a line would cost in the neighborhood of $3,000,000, including the cost of excavating, foundations, steel fabrication, field erection, cars and equipment, car stations, car barn and yard, two terminals and a fully equipped service to provide about a twelve-minute headway in each direction.

Mr. Coleman reported that while his committee considered the Whitestone branch only, he and his associates felt that if the operation of such a line proved successful, the system could be extended to Jamaica, hooking up with existing rapid transit lines and providing feeders to the existing services.

The Transit Chairman stated that he believed the system could be further extended providing a complete loop throughout the outlying sections of the Borough, providing immediate means of transportation to areas which otherwise would have to wait many years for rapid transit relief. One of the outstanding features of Mr. Coleman's report I believe to be the following paragraph:

"The further consideration that such a line can be built for about one-quarter of the cost of an elevated structure of the

existing type, and about one-tenth of the cost of a subway; that the operating ratio will be about fifty per cent instead of seventy per cent as now in vogue; that at least eighty per cent of the usual noises of elevated structures would be eliminated, and that the interference with light and air can be reduced to a minimum—should react favorably in analyzing this type of transit construction."

The Transit Committee's report was accepted by the Planning Commission and prompted that body to forward a resolution to the Board of Estimate and the Board of Transportation, recommending that the suspended monorail system of transportation be studied with the view of passing upon its value as a form of rapid transit for use in the Borough of Queens. The resolution is now before the Committee of the Whole of the Board of Estimate.

My own conclusion regarding monorail is that a new era of transportation has arrived. I believe monorail transportation will soon be a commonplace thing, accepted by the public just as readily as the motor car, the steam railroad, the subway and the airplane.

As to the solution of our own transit problems in Queens, I am optimistic that the suspended monorail will be the great factor in giving relief to the thousands of our homeowners without proper means of transportation and will have a marked effect in rounding out the development of our great Empire Borough. I fully expect to ride in a monorail car across the entire Borough in the not very distant future.

GENERAL ASPECTS OF THE SUSPENDED MONORAIL SYSTEM

By

FRANK S. LYON
President, Atlantic Suspended Monorail Corporation

THE lifetime of the American Institute, spanning over a hundred years, encompasses the whole era of the power-propelled vehicle. Your records chronicle the entire history of transportation since the stage-coach and the pony express.

Any development, to be comparable with the many outstanding achievements of this remarkable century that have been discussed here, must of necessity be of major importance. Leading transportation authorities and eminent engineers in every field of endeavor who have given study to the Suspended Monorail System of Transportation do not hesitate to state that it is of major significance and to predict that its inauguration in this country will begin a new page in our transportation history.

It is entirely in order to regard the Suspended Monorail System as a revolutionary development rather than as an evolution. It is a system of hanging cars, supported from a single rail above the load, with the center of gravity well below the support. Every animal-drawn vehicle, every surface train propelled by locomotive or otherwise, every automobile, every steamship, is supported from below and has the inherent possibility of overturning. A Suspended Monorail carriage cannot overturn.

In 1900 Eugene Langen built the first suspended electric railway, connecting the towns of Barmen, Elberfeld and Vohwinkel in the Ruhr district in Germany—a distance of 8½ miles. From the first day of its operation that line has functioned efficiently, safely and economically, and with increasing popularity. In the nearly thirty years of its operation over 800,000,000 passengers have been carried without accident to passenger or employee. During rush hours trains of three to six cars are operated at two-minute intervals. In test runs a speed has been attained faster than our subways. The cost of operation is less than any other system of mass passenger transportation known.

As early as 1910 the City Club of New York urged its consideration for use in New York City. In 1912 representatives of the German line were in the United States and presented complete details to transit authorities in New York and Philadelphia. Due to its unsightly appearance and to the fact that it had not been adapted to city transportation, it was not adopted. As a direct outgrowth of this effort, however, a group of American engineers, basing their studies upon these complete details of the German line, and realizing the necessity for an improved overhead system of rapid transit for eventual use in congested areas, undertook a serious study and refinement of this system for American use.

The engineers engaged in this activity were men of outstanding ability and in their studies they had the cooperation and assistance of many noted railroad and transit and electrical authorities. I am proud to represent this original group of American monorail pioneers and to have been identified with the project since the completion of their first studies. Our purpose has been to completely develop a modern rapid transit system, utilizing all of the proven advantages of suspended monorail transportation, including all of the remarkable developments in the electric railway field, and the remarkable improvements in modern structural practices during the past quarter century. It has been our purpose to secure actual bids from electrical and equipment concerns, steel companies, steel erectors and general contractors, and to definitely establish our ability to engineer and deliver completely equipped units, before making any announcement to the American public.

The distinctive advantages of Suspended Monorail transportation, the reasons for its relatively low cost of construction and comparatively small power and maintenance requirements, for its smoothness and quietness of operation, are engineering features which will be described in a non-technical manner by the next speaker. May I therefore briefly describe the appearance and the advantages of the system.

Essentially, Suspended Monorail is a continuous single rail from which cars are suspended. The bottom of the car is 15 feet or more from the street or crossing level, thus avoiding street surface traffic and eliminating the grade crossing evil.

Our structure for a double track line, of the capacity of a double track New York subway or elevated railroad, consists of a series of T-shaped towers running along the center of the street. These towers are three feet wide at the base and are placed 50 feet apart. Attached to each end of the T arm is a continuous 30″ I beam on which the running rail rests. There are no ties or roadbed between the rails. The bracing rods that are used between the two tracks or I beams to give rigidity to the structure are so small that they would cast little or no shadow on the street below. Stations are similar to present elevated stations, but due to the fact that our trucks and rails are above the car, the climb to the station platform is one-third less than to an elevated platform. The towers, only three feet wide, can be ornamental in design and can be joined by a narrow safety island dividing street traffic. By mentally comparing this type of structure with our present elevated railroads, we can readily visualize the slight extent to which light and air will be affected. Our rails and carrying structure above the cars are approximately 30 feet from street level, and will throw no considerable shadows.

Since the beginning of the century the most important innovation in rapid transit has been the automobile. Today, with private cars, taxicabs, buses and trucks, the street is no place for public carriers. Rapid transit lines must be above or below grade and must extend further out from the centers of population than formerly, because of the rapid development of out-

lying sections as a result of automobile transportation. Subways and elevated lines of familiar type are of course real rapid transit facilities, but it is inconceivable that a sufficient mileage of either of these can be constructed to meet the urgent need. The cost of the elevated is much lower than the cost of the subway, but its structure will always be objectionable for high class city streets or residential neighborhoods.

The Suspended Monorail System not only provides rapid transit of a capacity and speed equal to the subway or elevated, but its structure is not objectionable, even in residential sections. It offers a rapid transit facility for immediate relief as an extension to present lines and provides a complete unit to solve the problems of cities that are not supplied with any rapid transit. It is the only system known that will permit the construction of sufficient mileage to serve a city and its outlying neighborhoods at a cost low enough to be paid for out of popular fares.

Our position is that it is unnecessary in this day of improved structural practices and electric railway development to depend upon subways for rapid transit. Few cities outside of New York can absorb the bulk of the expense for rapid transit by taxes. Furthermore, we believe that the riding public prefers open air transportation, provided the same scheduled speed and equal facilities are available.

As I have stated, the Suspended Monorail offers an equal capacity at considerably lower cost both in construction and operation, with full capacity for speeds of either subway or elevated. In addition, it will render a service smoother and quieter. It is so designed as to cast scarcely a shadow on the street below. There is a shorter climb to station platforms than in present elevated practice. More cars are available because of the low cost of equipment and every item connected with it. Riding is free from lurching and swaying common to present two-rail systems. Safety is assured by eliminating all the common causes of derailment. Passengers are permitted a free and unobstructed view of the street below.

We believe that the Suspended Monorail System is destined o play a prominent part in rapid transit and suburban transortation in the near future; that the thirty-year record of the German line and the completeness of American improvements ustify its being employed to cope with present day transportaion problems; that its simple construction makes it possible o give quicker relief to rapidly growing communities than they ould otherwise secure.

We offer the Suspended Monorail System of Railways, an American product based upon a method of transportation that as, in actual operation, demonstrated its practicability and efficiency over a course of thirty years. The original conception of the Suspended Monorail has been developed and refined by American engineers, backed by the experience and resources of some of our leading equipment and structural concerns. We offer the composite of the best efforts of our engineers and of these great companies, a complete restudy of Monorail, with its development and refinement to suit American conditions.

ECONOMIC AND ENGINEERING FEATURES OF SUSPENDED MONORAIL TRANSPORT

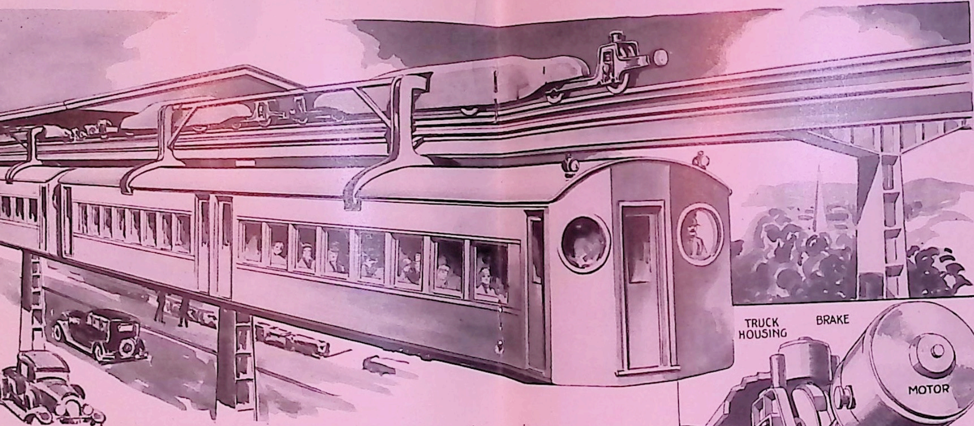
By

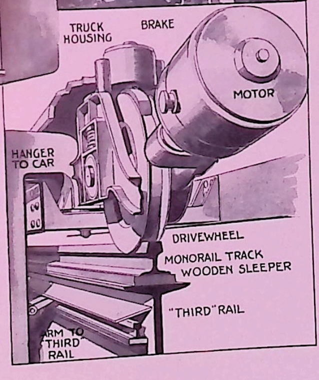
GILBERT D. FISH, Consulting Engineer

A STRIKING feature of rapid transit is that quality of service depends largely on quantity. The best appointed cars are uncomfortable when overcrowded. High speed does not compensate for long intervals between trains, or for blockading due to congestion at stations. A rapid transit system is not comprehensive unless it serves all neighborhoods.

Rapid transit, as distinguished from street car and bus transportation, is found only in a few cities, but is much needed in many others. A community of half a million population covers too much ground and has too heavy traffic to be served adequately by surface lines, yet there are about ten American cities of that size or larger which are getting along as best they may without subways or elevated lines. Several of them have prepared plans for such facilities, but the heavy cost is holding them back. New York, Chicago, Philadelphia, and Boston have rapid transit systems, all of them immensely useful but falling far short of the mileage needed for comprehensive service and for development of outlying districts.

Is rapid transit so expensive that only a few of our metropolitan centers can afford it, and that those few cannot support enough lines to meet their needs? Cost studies of subways and elevated lines of prevailing types seem to show that this is true. The elevated railways are far lower in first cost than subways, and might be afforded to a limited extent by some cities which now depend on surface lines, but they are regarded with general disfavor on account of noise and unsightliness.





SUSPENDED MONORAIL SYSTEM

OF

RAPID TRANSIT

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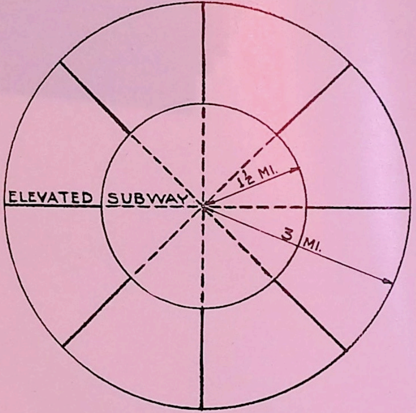

FIG. 1

Consider a six-mile circle having its center at the heart of a large city, and a rapid transit system laid out in lines radiating from the center to eight points of the circumference, as shown in Fig. 1. If each line is a double track subway within a radius of 1½ miles, and is brought above ground and extended as an elevated railway to the outer circle for the sake of economy, the system consists of 12 miles of two-track subway and 12 miles of two-track elevated, and its first cost completely equip-

ped is in the neighborhood of $100,000,000. If the area is densely populated, as it is likely to be if the city in which it lies has a million or more inhabitants, this transit system may take in 400,000 fares daily, or perhaps more after the outlying areas close to the routes increase in population due to the service. Not all of those living within the six-mile circle and desiring fast transportation will use the system, because 25% of the area is further than easy walking distance from stations due to insufficient number of routes. During rush hours, 3-car trains on 4-minute headway on each of the lines will carry the estimated load at 200 passengers per car, a condition of serious crowding, but no worse than what the public is accustomed to. Operating and maintenance costs will probably amount to 2 cents per fare, while interest and depreciation on the $100,000,000 installation will cost about 5 cents per fare. As the years pass, increase of traffic will somewhat decrease the operating cost per passenger and will reduce the carrying charges almost in inverse proportion to the number of fares, but a very large increase in business can probably not occur unless the lines are extended and the average haul increased.

If the carrying charges on the investment in a subway and elevated system are nearly as much as the revenue obtainable at ordinary rates of fare, even in such a populous area as the one assumed, there is not much chance of providing uncongested rush hour service at popular prices, using facilities of the types now familiar. Cities of the 500,000 class can hardly make as favorable a showing as the illustration chosen, especially if they refuse the economy of elevated construction in the outer zones. It is sometimes feasible to subsidize rapid transit construction in part out of taxes on realty which is enhanced in value by improved facilities, but this device does not actually reduce the cost of transportation; a better way of approaching the problem seems to be a study of the suspended monorail system.

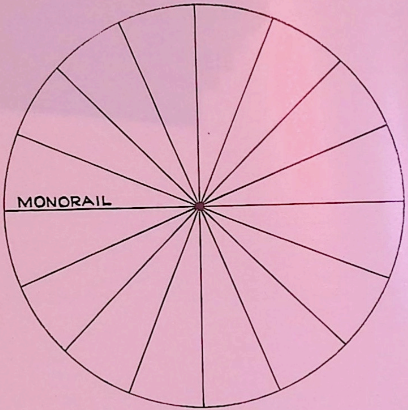

FIG. 2

Fig. 2 shows a layout for 48 miles of double-track monorail in the same six-mile circle previously considered. With twice the mileage of the other plan, this system serves all areas so that no point within the circle is more than easy walking distance from a station. If 400,000 fares a day could be collected by the eight radiating lines of the first layout, 500,000 passengers daily would be expected for this more complete system. Four-car monorail trains on 3½-minute headway on each route would not only handle the peak load but would provide a car

for about 75 passengers; as the seating capacity of a car is about 80, this service would leave nothing to be desired as to accommodations, and would be faster than that furnished by the other system because there would be no delays due to congestion at stations. The cost of the 48 miles of two-track monorail would be about $45,000,000, including enough cars for the service above described. While for equal service the monorail system would be much lower in operating cost than subways or elevated lines, the greatly increased service provided in the case here considered is estimated at about 2 cents per passenger, or the same as for the crowded and slower service of the first plan. Interest and depreciation on the $45,000,000 installation would be approximately 2 cents per fare, making the total cost of transportation about 4 cents per fare. Apparently in a territory offering 15,000 to 20,000 daily passengers per square mile of area conveniently served, fast and comfortable monorail service may be provided at a five cent fare. Lines extended into undeveloped districts might have to look slightly ahead for a satisfactory volume of business from those neighborhoods, but it is usual for apartment house construction along rapid transit routes to start before track is laid.

The potential importance of monorail transportation lies in the fact that it appears to offer a solution for the economic problem of rapid transit in most of the cities which need such facilities. In centers having a half million or more inhabitants, and perhaps in smaller ones, it should be possible to provide fast monorail transportation at prevailing rates of fare, with seats for all passengers.

The reasons for the economy and certain other advantages of the suspended monorail system are not obvious to everyone. A non-technical explanation may make some of these points clear.

The photographs herewith, showing the Langen monorail line in Germany, do not look like what is proposed for use in

this country, but illustrate the essential idea of hanging the cars from a single rail. Evidently, they cannot overturn as ordinary cars sometimes do, because most of the weight is suspended

below the support. The German line has run successfully for thirty years without guide rails to prevent swaying of the cars, and although there has been some disagreement as to how objectionable the rocking motion has been, the fact that the system has carried nearly a billion passengers seems to prove that the free-hanging trains have not been unpopular. The designs prepared by American engineers include guide rails to prevent swaying, as will presently be explained.

The trucks on the German monorail cars are very compact as can be seen in the pictures. It would naturally be expected that a single line of wheels would not require such heavy trucks as two lines. A more technical reason for lightness and simplicity of monorail trucks is that it is unnecessary to provide mechanical means to prevent rocking of the car bodies on the trucks. There is considerable looseness in the connections between two-rail trucks and car frames, but not in the hinge-type joints which provide for rotation of monorail trucks.

The monorail cars and structure, as re-designed for American service, are shown in Figs. 3 and 4. The cars are about the same size as those used in New York subways, 64 feet long and 9 feet wide, and provide seats for 80. Shorter cars may be used if sharp curves are required. The motorman's cab is elevated so that his eyes are slightly higher than the rail. The trucks provide 12 wheels per car, 4 of them being drivers. The trucks are so articulated that no more than two wheels are held rigidly in line. The wheel spacing is ideal in distributing the load along the supporting structure, and the flexibility avoids binding of wheel flanges on curves. Empty cars weigh 17 tons each, as against 40 tons or more for the usual steel subway cars. This great difference is due partly to the use of aluminum instead of steel for the bodies, partly to lighter trucks and motors, partly to smaller strength requirements of hanging cars. Of course, aluminum could be used for subway cars also, but weight sav-

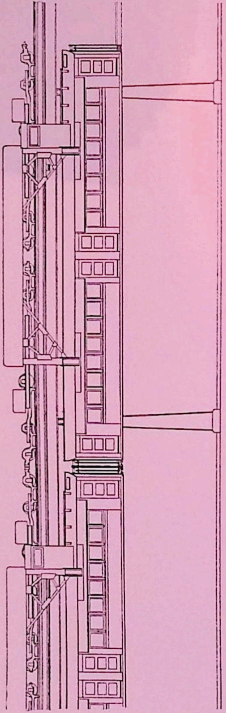

FIG. 3

ing is less important when there is no supporting structure to consider. Each monorail car is driven by four 50 horsepower electric motors, instead of two 200 horsepower motors as on subway cars. A conductor rail, fastened to each girder of the structure and protected against snow and ice, carries power for the cars. The design of wheels and motors is based on high acceleration and free running speed of 40 to 45 miles per hour.

The structure shown in the drawings, while not applicable in all locations, is considered the most compact and pleasing in appearance, and the least expensive, of several suitable forms. The T-shaped towers, variable in height but uniformly 14 feet across the arms and 3 feet wide in the shafts, are spaced about 50 feet apart; at the ends of their arms they support two lines of girders which carry the two tracks. The towers are cast into reinforced concrete footings which are big enough to stabilize the structure under the most severe conditions of unbalanced loading and wind pressure. The two lines of girders are braced by light steel trusses in a horizontal plane. Nothing in the structure is bulky enough to throw considerable shadows on street or buildings or to obstruct sunlight noticeably. On each girder is a wood sleeper which continuously supports the rail. The rail is a standard railroad T-rail, and is fastened to the girder with hook bolts. The wheels are double flanged, and resemble those used in traveling cranes.

The side clearance between cars and tower shafts is one foot; a greater distance would increase the cost of the structure and the space occupied by the system. So little space would be insufficient if the cars were allowed to swing free, and furthermore, it is desirable for the sake of comfort to eliminate swaying entirely; therefore, guide channels are attached to the towers alongside the car bottoms, and arms are provided on the car frames with rollers at their ends which travel in the guides and prevent swaying.

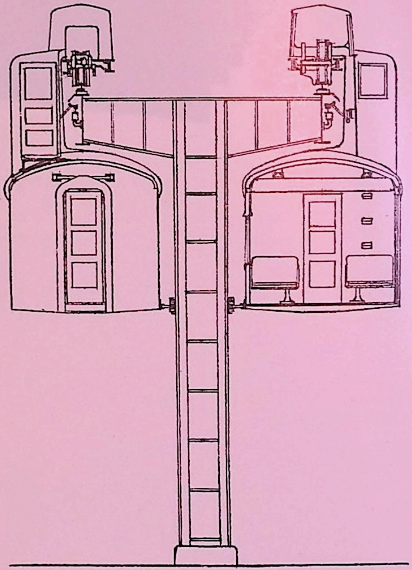

Fig. 4

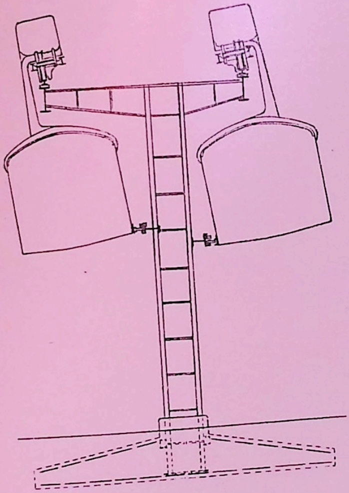

Fig. 5

On curves, the tower arms are of unequal length, and the guide channels are located so as to incline the cars at a suitable angle, as shown in Fig. 5. This corresponds to the inclination of an ordinary railroad track on curves, and is intended to balance centrifugal force, thus avoiding unduly high lateral forces and discomfort of passengers. No angle of inclination is correct for various speeds, but by designing for an average velocity it is possible to provide fairly well for all ordinary values. If the guides were omitted, the cars would always assume the inclination natural to the speed and curvature, but some swaying would result from the transition.

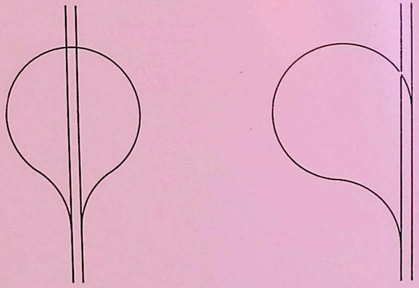

FIG. 6

Transferring a monorail train from one track to the other cannot be accomplished by the ordinary cross-over, because the train must be turned end for end to place the car hangers on the outside. Two plans of cross-over available for monorails are shown in Fig. 6. The one at the left is an elevated or depressed loop with two outside switches; it has the advantage of avoiding intersection where it crosses the main tracks. The one at the right uses one inside switch and grade intersection with one of the main tracks, a much more complicated arrangement mechanically, but better suited to some locations. At terminals, loops are provided instead of switches.

Station platforms are nearer the ground than in the usual elevated railway systems, because the car bottoms are only high enough for safe clearance of vehicles below. The saving in height is equal to the combined depth of car truck and supporting girder of the older system, amounting usually to about 7 feet. Fig. 7 shows that the climb from sidewalk to platform is about 16 feet when the headroom for street traffic is 15 feet. In the same drawing is indicated a metal safety net opposite the station platform, intended to catch persons who may be pushed over the edge and enable them to crouch in safety while a train passes over. Evidently no passenger can ever be crushed under the trucks or wheels of a monorail train.

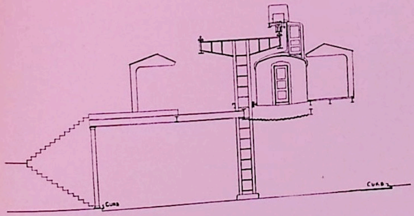

FIG. 7

The principal parts and manner of operation of the monorail system having been pointed out, some of its advantageous characteristics may be explained. The most important of these relate to cost, although some other features may have a stronger popular appeal.

The cars themselves are light and their power requirements are small. As power is one of the main items of operating cost, light weight is of great economic importance. Another major saving due to light cars is in the cost of the structure which supports them. Again, wear on rails and wheels is lessened by reduction in live load.

For structural reasons which would require technical explanation, the single-rail tracks and suspended position of trains make possible a remarkably simple and economical form of supporting structure. Light cars, advantageous weight distribution due to the wheel spacing, and absence of cross ties and flooring combine to save steel in the structure.

The structural design is based on arc-welded connections instead of riveted ones. Welding in steel construction is a fairly recent development which has brought many opportunities for reducing cost and increasing stiffness. The design adopted for the monorail structure is peculiarly responsive to the advantages of welding, and important economies would be lost if the plans were changed to permit riveted construction. Apart from cost saving, the welding method eliminates many clumsy and unsightly connecting pieces and provides smooth surfaces unmarred by rivet heads. The impossibility of welded joints working loose is another point in favor of the method. The welded anchorage of towers to reinforcing steel in the foundations could not be replaced by any riveted equivalent; an expensive change in the design would be necessary if welding were not available. Silence is a strong argument for welding as against riveting.

Another important saving in first cost is in the track. One rail is used instead of two, and that one is of lighter section than those used in subways. On ordinary track under heavy traffic, the rails must be deep and heavy to bridge the gaps between cross ties, and their heads must be of large cross-section in order not to require frequent replacement on account of rapid wearing down on the inside. Monorails are symmetrically loaded and suffer no grinding action at the sides; they are continuously supported by wood sleepers and therefore do not require strength to bridge between ties. Most of the original rails of the German line are still in service after 30 years. A large item of saving is the elimination of cross ties and other heavy timbers.

The single rail with no adjacent flooring is remarkably easy for a motorman to watch. Furthermore, accidental obstructions are most unlikely to lodge on the rail, because in the absence of nearby supports they would have to be nicely balanced to remain in place. Very little track-walking is needed for adequate inspection, and re-alignment of rail is not a frequent or expensive operation.

There are advantages in monorails other than economy, a very important one being quiet operation. The driving mechanism and wheels being above the cars, no noise is reflected downward by the car bodies as on ordinary elevated railways. Special care has been taken to provide gears of especially quiet type, to use roller and ball bearings throughout, to house the machinery in a hood with sound absorbing lining, and to provide a continuous wood sleeper as a cushion under the rail. For reasons which will be made clear presently, there is no lurching of the trucks from side to side and no grinding of wheels on curves, two sources of much noise on two-rail tracks. The comparative quietness of monorail operation is a feature to be taken into account in considering the system for residential districts and business streets of the better class.

In a two-rail track, even with very careful maintenance, slight ups and downs occur in both rails; these irregularities being accidental, the track is in most places slightly out of level transversely, one rail being alternately higher and lower than the other. The effect is to rock the trains, especially at high speed. Another action is lurching of the trucks right and left; slight imperfections of alignment are sufficient to cause this, and it can result also from unsymmetrical brake action and from the lurching above mentioned. The two motions described are exceedingly disagreeable to passengers, cause rapid wear on track and wheels, and are sometimes severe enough to derail a train. In monorail service, the cause of rocking above described is absent, and sidewise shifting or "nosing" is prevented by the double-flanged wheels and the close fitting truck joints. The single rail has all the advantages in the matter of smooth riding qualities.

On curves in two-rail track, the axles in each truck are held parallel and therefore cannot remain strictly at right angles to the track; in other words, the wheels are skewed on the rails, and the wheel flanges grind against the rail heads if the curvature is sharp. This accounts for the screeching noise heard at sharp curves, and for part of the high resistance which curves offer to the passage of trains. Furthermore, the wheels slip on the rails due to unequal distance along inside and outside rails. Both effects cause rapid wear of rails and wheels, retard trains and cause noise. Neither action occurs at all on a monorail.

Very little has been said about speed, mainly because there is nothing to be gained in local rapid transit by designing equipment for velocities which cannot be attained in the short intervals between stations. Gears suitable for high free-running velocity cause slow starting. When distances between stops are short, the most important factor in quick station-to-station travel is fast pick-up or acceleration, not high maximum speed. Even in express service such as is furnished on rapid transit lines of three or four tracks, very little time can be saved by increasing

the free-running speed from 40 to 60 miles per hour, unless stops are two miles or more apart.

Therefore, from the standpoint of transportation within a city, it matters little whether the monorail system has inherent possibilities of exceptional speed or not. This question is often raised, however, and is an important one in connection with any plans for inter-city express service. If sufficient demand should arise for medium or long distance passenger or express parcel service at higher speed than is offered by existing electric and steam railroads, the monorail would meet it. In speed possibilities, it may be said to occupy a position intermediate between two-rail systems and airplanes.

There is no definite limit of speed possible with electric motors, but safety and economy both appear as limiting factors which prevent developing the potential capacity of any type of motive power as far as might otherwise be done. There are several basic elements of superior safety in the suspended monorail system which will justify unprecedented service speed if commercial demands warrant. One of these is the stability inherent in cars having their centers of gravity below the support; overturning is impossible. Another is the elimination of rocking and nosing, which are serious on a two-rail track at very high speed. Another is the impossibility of "spreading" of rails, which has derailed many trains. Again, the rail is held by bolts which hook under the steel girder flanges, instead of by spikes or screws in wood ties. Finally, a simple device to prevent a wreck in case of derailment is a series of safety hooks, two to a car, which are made parts of the car frame and extend across and slightly above the top of the rail; these hooks are designed to catch on the rail and arrest the fall of the car after a drop of an inch or two, and to slide along the rail until the train is brought to a stop by friction.

The principal changes in the design of the system for high speed would be increase in power of motors, change of gear ratio, limitation of degree of curvature of the line, and some strengthening of cars and structure. Automatic block signals, which are of course included in the system as proposed for local rapid transit, would be retained without change except to lengthen the blocks.

It would be feasible to provide for free-running speed of 150 miles an hour. The air resistance would be very high and would make it advisable to taper or stream-line the front and rear of the train to reduce this retarding force. Very powerful motors would be required, and they would be geared for high speed at the expense of acceleration; that is, they would require a number of minutes after starting to reach full speed. A non-stop run of 100 miles would require about 45 minutes if curvature and grade were slight.