Thesis
A Study of the Boynton Bicycle Railway

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After some years experiment, there has been developed the Roynton Bicycle Railway, which is believed by those interested in it to be a very great improvement over the present system of railroad transportation, introducing therein great economy in construction and operation and increasing present facilities many times.

The advantages claimed for this system by its inventor and promoters are first, the reduction of the track to a single light rail, thus avoiding most of the train resistance arising from a necessarily uneven two rail track, and allowing the attainment of a much higher speed consistent with safety and comfort than is now reached upon railroads; and, second, the reduction of the weight of the train by the new style of
construction introduced. By these two radical changes, the bicycle train is intended to be far superior to the present one on the standard gauge track in the matter of ordinary frictional resistance, and that due to curvature and grade.

In attempting a study of the subject in its relation to the different forms of transportation, I shall first consider briefly the theory on which the operation of this road is based, the use of the so-called "bicycle principle," then passing to a comparison of the bicycle railway with the roads operated for city and suburban rapid transit, and the ordinary trunk line or local standard gauge steam railroad with regard to construction,
operating, and the rendering of satisfactory service.

The principle of the bicycle is well illustrated by a rolling hoof of a bicycle which, though while at rest it can not maintain a vertical position, does so if rolling forward with sufficient speed. The explanation of this is probably that, as the body begins to tip to one side, it begins to move in a curve and the centrifugal force due to this curvilinear motion restores it to a vertical position.

There may arise the question as to how far this principle applies when the wheels are flanged and confined in their curve to a rail, thus being deprived of freedom to side motion in order to preserve verticality. With the overhead guide
rail, however, there could be no overturning, and the only result would be to possibly increase the resistance and make the car run somewhat less smoothly.

The chief aim of this invention is to reduce to a minimum the friction of a moving car, by the avoidance both of the lateral motion due to inequalities of the rail and the slipping and grinding of the wheels and rails on curves. On the standard gauge track it is practically impossible to keep the two while at exactly the proper grade at all points so as to maintain a perfectly even track. A passing train reaches a slight depression of the rail and, as the center of gravity of the car is between its two lines of support, it tips and strikes
with more or less force against the low rail, then it may rebound against the other, or strike an uneven spot in it and lurch to that side. Thus this lateral motion is continued while the train is in motion, and the more uneven the track, or the higher the speed, the greater it becomes. Besides being uncomfortable for passengers, it may reach a point of real danger and will in any case result in a considerable increase in train resistance due to the friction and concussion.

With only one rail the center of gravity of the car is directly above the point of support, and so a deflection in the rail would cause no lateral, but only a vertical motion. This avoids the danger of spreading of the rails and de-
railment at high speeds and adds
to the comfort of the passengers, while
rendering high speed possible of
attainment by the easier running
of the cars and causing, perhaps,
less wear and tear of the road
bed.

It is claimed that the bicycle
system effects a great saving of fric-
tion in passing curves, on account of
the entire absence of wedging and
sliding of the wheels on the rails,
which causes a considerable loss of
power on the ordinary track. Where
narrow-gauge roads are mentioned
as being that a narrow gauge
allows easier passage of curves and
so the narrow-gauge, the single
rail, is best. But the decrease of
curve resistance is slight unless the
wheel base is shortened as well, so
that standard gauge rolling stock, which can have a shorter wheel base than narrow gauge rolling stock can have, may face the same degree of curve as easily or perhaps slightly better than, narrow gauge cars. While the cars running on two wheel only, would certainly face curves with a minimum of reluctance, with these bicycle cars having two wheel trucks, this would be somewhat more, due to the sliding of the wheel.

It might at first seem that there would be a large amount of friction between the guide wheel and rails, a space of one half inch being left between them; the wheels would be continually striking against either side of the rail. But it is said that those who have had opportunity to notice them have found the wheels to be much of the time out of con-
Start with the rail, and that there is no appreciable wear of the wheels. The locomotives were so evenly balanced that a person on a level with the guide rail could easily tip them from side to side, and, if space enough for lateral movement is left between the guide rail and wheel, the train can balance itself to a considerable extent on tangent. Hence this rail is even pronounced unnecessary, except at stations where the trains are standing, and on curves, for the faster the motion, the steadier it is, while on the present railroad the opposite is true.

A very high wind would press the guide wheels against the rail increasing the fiction and, it might be, tending to overturn the whole structure. This would depend on the
construction of the track, with regard to
the stability of the structure; the length
of ties, how well embedded, the fix-
ing of the vertical posts, and whether
double or single track, as well as the
weight of the train, for the cars
would be very light, yet with a
large area exposed to the wind.
It is said, however, that the road
has been well tested in this par-
ticular in actual operation on
Long Island, and that no diffi-
culty has been experienced, even in
passing a high tide, exposed to
strong winds from the ocean.
The upper rail evidently could
not be dispensed with if the wind
pressure is to be taken into account,
and it is suggested in the company's
catalogue that the guide wheel could
be brought to bear against it on heavy
grades and so increase the traction. Power would of course have to be suf-
ficid them at the expense of the motor wheels or drivers, and there
would be the added friction of their bearings and rolling surfaces so that the result would be a loss rather than a gain.

It seems entirely reasonable to say that, if the bicycle system is, in other points practicable, and the claims made as to the easy and well-balanced running of the train are true, it should avoid very much of the train resistance due to oscillation at high speeds and its curvature.

Atmospheric resistance could not be to any extent done away with, except in so far as the narrow, wedge-shaped ends of the cars diminished
it, but would be increased if it were possible for the trains to reach the speeds of sixty to a hundred miles an hour promised.

The resistance due to grade, which is constant per ton for a given grade, is intended to be decreased in amount by the use of very light cars; and the smaller number of bearing surfaces would also eliminate some friction.

The cars are extremely narrow, being four or six feet wide, forty-two feet long, and, in the case of the two story ones, fourteen feet high. It is expected that in making them narrow and deep like a beam, they will have greater strength with less material than those of more nearly square section on two-rail tracks. This may prove
to be correct as long as the car is
held in position by the axle, but in
case of accident, when it might be
subjected to extraordinary force di-
rected against the sides, it would
seem that the car would be weaker
by a considerable amount because
of its narrowness. Extreme lightness
of the car is obtained by their
construction, in coffins, made of
wood veneer only three-eighths of
an inch thick, strengthened and
held in place by steel bands and
rods, running lengthwise, vertically,
and across the car.

Those seating 108 passengers weigh
5 tons, and those of one story seating
54, weigh 3 1/2 tons. It seems very
doubtful if such light car would
be found strong enough to with-
stand the shock of a severe col-
lesion and resist being crushed and completely wrecked. They are suspend-
ed by springs from the vertical shaft, to which the truck or wheel axle is attached, and which carries and turns with the guide wheels above. The ends of the car exposed to air resistance are wedge shaped, and in a train the spaces between cars are to be vestibuled.

In connection with elevated roads this system has some apparent ad-
vantages that seem to render it peculiarly well adapted to city and suburban traffic. It could in cities or populous districts, only be operated on an elevated or depressed track, because of the speed its trains should easily make, and which if attained, would be an important point in its favor, and
because of the obstruction the posts and overhead rail would cause. Electricity, now the great motive power on street railways, seems equally well suited for elevated roads, and the bicycle system appears to be especially adapted to its use. On account of the light weight and narrowness of the cars, much lighter and narrower structures could be erected in the streets, occupying less room and shutting out less light than the present cumbersome ones.

The cars of the New York elevated roads seating 48 persons weigh 15 tons, while the bicycle cars of nearly the same capacity weigh 3 1/2 tons, so only about one quarter as much power would be required to move the bicycle trains if locomotives were used. Electricity
could probably best be used, thus doing away with the noise and dirt from the locomotives. Property along the line would be benefited by the facilities afforded by the road, without, at the same time, many of the disadvantages tending to depreciate it. The overhead structure, supporting the guide rail, also carries the current rail firmly held between the two sides of the hollow rail, which avoids all danger of falling or of contact with other wires. The bicycle railway company agrees to transform the present elevated double track road now in operation into four track bicycle road with only the additional cost of the upper structure. Changes would have to be made in the track arrangements at switches, and
on curves the present gauge would need to be widened. The distance from center to center of rails is nearly six feet, depending on the size of rail, and with care only four feet wide there would be about one foot clearance left between them. The New York elevated road has curves of ninety feet radius, and equally sharp ones may be found on other elevated roads. Then, with forty-two foot cars and distance from center to center of wheels, or of trucks in the case of four wheel cars, twenty-six feet, the center line of the car would overhang beyond the rail about nine tenths of a foot at the center and a foot and a half at the end. On such curves or even those somewhat easier, it would be impossible for trains to pass without widening the
gauge nearly a foot, and a half at least.

For four tracks where there were previously two it would be necessary to provide additional platforms with stairs, or perhaps stairs and an overhead crossover, to reach them, entailing a large expense and in some cases perhaps necessitating a spreading of the tracks and an enlargement of the whole structure at stations. If two story cars were to be used, it would certainly be necessary to build an upper platform for the upper compartments. Extra steps to mount are to be avoided, but they may be preferable to standing in the cars.

One feature of this system possessing more than ordinary value is the facility with which the bicycle can...
can discharge and receive passengers. They have a door for each compartment, giving nine on a side in the one story, or eighteen in the two story cars, and so can, with a door for every four or six passengers instead of one for every twenty-four, admit them much more quickly than with one at each end. This would reduce the time necessary for stops at stations to about one-fourth that required with the other style of cars, and, with the time lost standing still at stations about one-fifth or one-fourth of the total time consumed in a trip, the latter would be reduced nearly one-sixth. The lighter cars and use of electricity would also effect a saving in time needed to get under way from stations.

With four tracks available, two
would be used, for a part of the day at least, for express trains making few stops, and it is claimed that they could easily be run at sixty miles an hour on the bicycle road. But if the standard gauge of the tracks remained unchanged the high shed would seemingly be attended with some danger. If the two middle tracks were given up to these trains, there would be only five feet between them and the platforms where local passengers would be standing, and the draft created by these trains at such a speed might, unless proper precautions were always taken, cause some serious accident even with a fence to separate the tracks, perhaps being strong enough to draw a fusee in front of an approaching train on the local track.
It would probably be safe to run such fast trains only at considerable
distances apart, to avoid all possibility
of collision from failure to bring them
quickly under control. But aside from
this, any such speed would be possible
only on tanguite, and would then be
objectionable because of the noise, dust,
etc., and would really be unnecessary
as the time could be sufficiently short-
ened by making fewer stops. The
lighter weight and easy running of
the cars would bring less strain
upon the whole structure than the
rolling stock generally used at present.
Now it may be asked if nearly or
quite equal facilities could not be
provided without abandoning entirely
the present system for the bicycle,
and I believe they could. Certainly
the same, or some, method of construc-
tion similar to that employed in the bicycle cars could be used in building the ordinary coaches, such as run at present on elevated roads, and which have about the same length, and thus gain the lightness that is one of the chief, if not the chief, point made in favor of the bicycle train, allowing the attainment of high speed with the expenditure of very little power. The standard gauge cars nearly ten feet wide, might not perhaps be easily made as light in every particular as those only half that width, although there would seem to be no practical reason why they could not, but, in any case, the one car ought to be made as light as or lighter than the two separate narrow ones occupying the same rail space. The New York Elevated cars weigh...
about 15 tons, and as two of the lightest of those on the bicycle road weigh together 8 tons, the former could surely be brought down to nearly the same weight, provided they are strong enough to be serviceable.

As I have said, they seem to be too lightly built, though it is said there has been no strain on the work in stopping the train when running at seventy miles an hour, and that the varnish in the corners was never cracked; they had not however been through any accident to test their strength. Still they would probably be strong enough for this kind of traffic where bad accidents would be of the rarest occurrence. The bicycle company asserts that it is impossible to run as light cars on a standard gauge road, that they...
would leave the track because of the lateral motion. While this may be true at very high speeds, it would not hold for such speeds as would be required on an elevated road.

These cars could also be operated by electricity, perhaps from a third rail, thus avoiding the necessity for an overhead structure and yet be quite as safe as the bicycle current rail from falling or firm contact with other wires.

They could be provided with side doors giving as many places for it as in the bicycle car. With this arrangement of seats across the car, those ten feet wide would seat ten persons in a compartment, while the narrow car could not be over four feet wide and would seat but eight in the two corresponding compartments.
of the two cars. The capacity of the standard gauge would thus be twenty percent greater than that of the A-cycle cars. The bicycle trains would however have one advantage, that some of them could be run as express trains without interfering with the locals as there would be four tracks available and thus would probably compensate for the twenty percent lack of seating capacity. The standard gauge cars, if made lighter and operated by electricity, could certainly make as high speed as desirable with little loss of time making stops and starting from stations.

So it appears that they could be run on the present elevated roads so as to give very nearly, if not quite, equal facilities to those of the bicycle road with much less expensive al-
trations, and, that great changes would be necessary for the install-
on of the bicycle system on the present standard gauge track than is represented by the company interested.

When the elevated road is originally intended for operation by the bicycle system, and the structure is design-
ed and built accordingly, this may prove more advantageous than other systems of transit.

The structure designed for a single track elevated bicycle road consists of a beam or girder, carried on a single line of posts, on which the sail rests directly. The upper sail is supported by thin rectangular frames, fastened to the girder and wide enough for the trains to pass through. These also support a system of longitud
inal and diagonal rod and brace, tending the whole structure. For a double track, the rails are carried on two girders supported on only a single line of posts, and braced laterally by latticed frames. Cross pieces, self-supported by smaller posts between the rails, carry the guide rails which are braced laterally. While the single track may break on its one line of posts, though apparently lacking greatly in lateral stiffness, which might be remedied somewhat by the rod and brace connecting the vertical frames, the posts carrying the double track are continually exposed to a very eccentric loading that makes the stability of the structure shown in the catalogue doubtful. With the motor cars and lightest coaches, when full, there would be
a load of about 10,000 pounds on each foot at a distance of nearly three feet from its center. Then, considering the possible length of columns and the impact, it is evident there would be a severe strain put upon the structure. Columns that were heavy and strong enough would be so large as to cause nearly as much obstruction as a double line of light foot, and so it would be better to use the latter where possible and save in material.

Where a double track road is built it is proposed to have one track on each side of the street near the curb. Being so light and narrow it leaves the middle of the street unencumbered and more open to sunlight, and, although near the side, its lighter construction than that of
the two rail tracks darkens the office and stores less, rendering them somewhat more valuable. If four tracks are built, two are to be on each side of the street on the single line of posts. The two or four tracks, as the case may be, can also be carried through the middle of the street on the one or two lines of posts, depending on the number of tracks.

A four-track road would be only sixteen feet wide, with the posts twelve feet apart, and so would not shut out the light from buildings, nor darken the street below but little. At stations there would need to be at least two platforms, and it would wider out to take up nearly as much space as would the standard gauge system. In any case it shdld if it gave equal facilities be somewhat
less objectionable to property owners than the latter.

The bicycle car economize their space better than the others in the arrangement of seats, and by the location of several doors at the sides instead of one at each end, they possess a still further advantage in combining greater seating capacity with increased means of entrance and exit, so that the result is a shorter stop at stations instead of a longer one as would be the result of any attempt to increase the capacity of cars having only end doors.

The trains are, as it were, also split in two, so that during the hours of heaviest traffic, or through the whole day if necessary, express trains can be run and clear the road of a large amount of business sooner than
otherwise.

The road could be extended into the surrounding suburban districts and the Expyee trains run through between them and the city in the morning and at night, as they could be made up of any number of cars, or even one alone, if operated by electricity with each car having its own motor, or using separate motor cars. These ex-pyee trains could, on an elevated road, make very good time both in the city and suburb, thus showing superiority over the surface electric lines in their high shed.

There would be an advantage over the standard gauge, elevated road, from the fact that the latter would require twice the amount of track to run express trains and so
give equal accommodations. They would be best suited for less frequent, longer, and heavier trains thus concentrating the traffic, while, on the other hand, the bicycle road with its lighter cars of smaller capacity, and with twice the number of tracks, could distribute it among two or three times the number of trains, so preventing much of the crowding of stations by waiting passengers.

With stations near together it would not be necessary, even if perfectly safe, for the express trains to run at very high speed to shorten the time, as a sufficient decrease in the number of stops would alone shorten it to a considerable extent, possibly as much as twenty-five per cent. Some figures given in Wellington's Theory of Railway Location on the
average time consumed on the Third Avenue line of the Manhattan Elevated road, where the total time for a single trip being forty-two minutes, fifteen and a half were lost in twenty-six stops in eight and a half miles.

The lighter construction and consequent cheapness would in many cases allow it to be profitably extended from the city into the Suburbs. This seems to be that for which the system is best suited, that is for the construction of new elevated railroads, not its use on those already built and afterward adapted to it, but on those originally planned and built for it. The road, even for four tracks, would occupy so much less space that it is particularly well adapted to streets so narrow that there must be as little as possible
obstruction to the traffic of the street and to light, or to broader streets, as well, while it is also desirable to have no more obstruction than necessary. Neither could there be as much opposition as far as appearance is concerned either in the city streets, or in the suburbs, where any unsightly structure is often out of place and would be objectionable to residents.

In some cases the bicycle elevated road could, because of better facilities in some respects that it would give, be built with only two tracks where a double-track standard gauge road would be insufficient. Then, the light narrow structures at the sides of the streets in the city would occupy little space, and outside, where its appearance might be objectionable, would be less conspicuous.
Thus the charter and right of way ought, under the same conditions, to be more easily obtained for an electric bicycle elevated road, while the damage to neighboring property would be less, owing to the absence of smoke and dirt, and the smaller structure.

The cost of the single foot, double track, steel structure is given as sixty-five thousand dollars per mile, or about one fifth that of the present elevated railroad structures, based on the statements and estimates of iron manufacturers. This does not seem to be too low a figure for the light structure shown in the catalogue, unless the posts needed to be excessively heavy for the reason I have mentioned. A similar double track structure supported by two lines of lighter posts ought to be as cheap as, or even cheaper than.
the other, as the loads are light and the very eccentric loading of the single line of columns would be done away with. For a four track structure the cost would not be far from double that of two tracks, or $115,000 or $120,000 per mile would probably be a fair estimate, although none is given in the catalogue.

The cost of stations and platforms would be very much the same as for standard gauge elevated roads, if one story trains of the same length were used. For two story cars the upper platforms would have to be built with their stairs, or elevators might perhaps be used at stations where the number of passenger accommodations was very great and the height of platforms considerable. At stations liable to be seriously crowded, with the same amount of work, there would
to much more freedom from overcrowding, especially in entering and leaving trains, owing to the convenient location of the car doors on the sides, thus distributing the passengers waiting for a train along its whole length, instead of concentrating them at five or six points, and facilitating their passage to or from the cars. So the stations could for the sake of economy, other things being equal, possibly be made some smaller than on the present roads, subject, however, to future enlargement. With stations so near together, it would be difficult to double the average speed of the present elevated roads to twenty or thirty miles an hour, for trains stopping at all stations, as is provided for the bicycle road. It would seem that, unless some very efficient brake were used, a much larger pro-
portion of the time would be consumed in slowing down to a stop than at present. The one-story cars seating fifty-four weigh about 130 pounds per passenger, the two-story ones seating one hundred and eight weigh 93 pounds per passenger. The former would, then, weigh twice as much when full as empty, and the latter about two and a half times as much. In order to bring a train, with such wide variations in its weight at different times, to a stop from a moderately high speed in as short a time as possible, it would of necessity be necessary to use some brake that would automatically regulate the braking power according to the speed and weight on braked wheels, decreasing it as the speed and weight decreased. Some form of electric brake could be used on this electric road and would
seem to meet the requirements of the case. For as the braking force comes from the armature, if the car wheels begin to slip on the rails, the current and as the braking force, is cut off. This would give power just up to the point of skidding the wheels, and yet prevent skidding.

By some such means, being able to make the stop at a station quickly, as well as to start quickly therefrom after a short stop, the time necessary for one trip should be considerably shortened from what would be required on the present elevated railroad.

In the whole, the bicycle system as applied to elevated Grade seems in several respects peculiarly well adapted to afford rapid and convenient passenger transit, both for
city and suburban requirements, and, at the same time, is in some ways less objectionable than the common system of elevated roads. With sound and safe construction, there seems to be no reason why a high degree of safety should not be attained, and it has the additional advantage of simplicity and of being probably quite as cheap as any other.

While the bicycle system has been to some extent tried with light passenger traffic, similar to what has just been considered, on the Sea Beach and Brighton, and Long Island Bicycle Railroads, and has there, according to the company's statements, proved itself an unqualified success, it has not been tried with through long distance freight and passenger traffic. Yet, it is claimed that the advantages of the
road in this direction under it far superior to the ordinary two rail sys-
tem.

Starting with the subject of con-
struction, this system is expected to ef-
fet a great saving of expense in
grading and land damage. Yet
this saving would not be as great
as might at first appear possible,
if the road was built on the sur-
face. For, where on standard gauge
roads the road bed should not be
less than twenty feet wide in cuts
to facilitate proper maintenance,
nor much less than fifteen feet in
fills, on the bicycle road the reduc-
tion in width of the road bed could
not be much more than the width
of the standard gauge. It might
possibly be made more because of
less trouble in maintenance, due to
the decrease in weight of trains and 
the elimination of most of the lateral 
thrust given the track by their sway- 
ing and jiking, which would allow 
subgrade, a narrower roadbed in pro-
portion to width of track. 
The frame supporting the guide 
rails however would be as wide as 
the standard gauge if four-foot cars 
were used, and still wider if six 
foot cars, as would undoubtedly 
be the case in order to meet the re-
quirements of through passenger ser-
vices we run. If the road accomodat-
ed freight traffic, the bicycle freight 
cars are given in the catalogue 
as five feet wide. Then the ties 
must be long enough to have suf-
ficient bearing to properly distrib-
ute the load, and this would be 
not far from one half the length.
used on the standard gauge, or about four feet.

The width of road bed, then, could not be safely decreased more than five feet, and this would mean only a comparatively small decrease in the quantities of cut and fill, where the sides have a slope as great as one and a half to one. For in the case of twenty foot wide cuts, the per cent of decrease in total quantities corresponding to one of five feet in width of base, is only about eighteen per cent for cuts of five feet, regarding them as level sections, and diminishes as the depth of cut increases. In fills with width at top of fifteen feet, the corresponding decrease in total quantities is much less. Where the material to be excavated permits of a
steep. slope as in rock cuts, of course
the per cent of decrease is greater
but would not exceed twenty-five or
thirty per cent, while in the greater
part of excavation the sides
would have a slope of as much
as one and a half to one.

It might be claimed that,
by the use of the step grades pos-
sible with the bicycle system, the
depth of cuts and fills could be
diminished. This may be true to
a certain extent, but yet the road
could not follow closely the un-
dulations of the surface and the
amount of earthwork would still
be very great.

In Roe's Manual for 1889, it
given the cost of various items of
construction on the N. Y. C. & H. R.
P.R. as follow:-
<table>
<thead>
<tr>
<th>Category</th>
<th>Amount</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridgework</td>
<td>$29,134,880</td>
<td>3.3%</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>$30,982,404</td>
<td>34.9%</td>
</tr>
<tr>
<td>Station etc.</td>
<td>$14,931,078</td>
<td>16.8%</td>
</tr>
<tr>
<td>Land and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land damage</td>
<td>$16,033,740</td>
<td>18.0%</td>
</tr>
<tr>
<td>Engineering</td>
<td>$30,182,879</td>
<td>34%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$104,363,419</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

This may serve, in a measure, as an imperfect illustration of the proportion due to each of these items. Then if the cost of grading were directly proportional to the amount of cut and fill, the bicycle system would have made a saving in the matter of grading alone, on that road of not more than about four percent. The percent reduction in cost of masonry would be different.
with different structures, but would, very likely, on the whole be the same as with the grading. As the figures are not given separately for the grading and masonry, I will take four per cent as the decrease due to the one item. In building a double track road the amount saved in these two items would be doubled, but the percentage saved would not, although it would be increased.

In the expense due to land and land damages but little would be saved by taking a right of way only a few feet narrower than for a standard gauge road. The cost of rails, if one sixty pound rail was used instead of two ninety pound, would be only about one-third, the cost of ties...
would be nearly one half, and the cost of ballast be reduced still more, to about one third. But the overhead rail and its supporting steel frames and bracing would make up for the reduction in cost of rails, and no great decrease in cost of superstructure could be expected, though the cost of construction might by this one item be diminished slightly.

It is stated that this system would save a great deal of expensive construction in mountainous regions, and it certainly would do so, but still, a narrow space sufficient for the single line of rails would not, as claimed, be sufficient unless there was room for the cars, and, if not, room would have to be made. In such places precautions
would need to be taken to ensure the safety of the guide rail against falling timber or rocks.

The cost of bridges would be very materially decreased but the total cost of construction would be thereby diminished not more than one and a half or two per cent.

The cost of stations, fencing, etc. would be the same as on the ordinary railroad.

In order to operate the present standard gauge roads by means of this system, the freight cars as designed would need to be one foot narrower, diminishing their already small capacity of seven tons twenty per cent, and making them less well suited for freight service than before. While on curves no sharp-er than ten degree there would be no
Absolute danger, there being just room enough for two narrow trains, bringing them extremely close together, in yards or where very sharp curvature existed the gauge would have to be widened.

The locomotives that have been built and used on the bicycle road had a total width of four feet, six inches, which would be too great to allow them to pass on a standard gauge road. A decrease of six inches or more in the width would diminish considerably the grate and boiler capacity and consequent ly the power of the locomotive, especially for high speed passenger service in which steam producing power is the point at which failure is most likely to occur.

From the preceding comparison
then, it does not appear that the
bicycle road would introduce such
economy in construction that it should
displace the present system, unless
it brought about a great saving in
cost of operation, furnishing at the
same time facilities for all classes
of traffic equal or superior to
present roads.
The question of safety enters into
the construction of the road, in
regard to highway crossings, more
than that of others, for the long
line of N frames would control
an approaching train quite effect-
ually, depending somewhat on the
alignment of the road. This would
in any case, if trains were run by
electricity, at the high speed fore-
nixed, be such a source of danger
as to prohibit any grade crossings
unless protected by some apparatus always sure to work properly, and this would add a considerable expense for the necessary bridges over road or highway, or for the protection of the crossing.

I have in considering the relative economy of construction taken the road as a surface line, for I regard the idea of elevating a road of any considerable length throughout the whole distance as impracticable because of the irregularities of the ground. It is said the elevated electric bicycle road can be built of Georgia pine for $20,000 per mile of double track which may be a reasonable estimate for the structure alone as shown in the catalogue, but, except in a region with a very even surface, there would be heavy
earthwork necessary, or else very high trestling would have to be erected to. The latter might result in the loss of a certain amount of passenger traffic because of the structure's unsafe appearance to some people. The expenses at stations would be largely increased if elevated.

The bicycle road could, if the various resistances were as far diminished as is claimed, be operated on much steeper grades than is economical or possible on standard gauge roads. This would be more true with electric, than with steam power, the absence of curve resistace would admit of some increase in maximum grades, and also allow considerable development for the surface of reducing the grade, and
consequently the cost of operation. This opportunity to employ a steeper maximum grade and sharper curvature would of course very materially decrease the cost of construction in difficult locations, still there would be a limit to the grade that could be used, and excessively sharp curves would not be advisable where trains would have to travel at high speed, as there would be liability to constrain such a structure as would be built.

It is claimed the operating expenses could be reduced one half. On the average, there will be about twenty-five or thirty percent of the operating expenses on the railroads of the United States due to the salaries of agents, clerks, and general office, station service and
supplies, all of which goes to make
up the great cost of conducting
transportation, taxes, insurance,
legal services, telegraph, advertising and
miscellaneous items, none of which
will be much affected by the amount
of business or the character of the road.
From the nature of these expenses, they
would not be materially decreased by
the use of the bycycle system, and
so may be left out of consideration.

Maintenance and Renewal of Way
according to the statistics shown by
the Interstate Commerce Commission,
and as given by Wellington in his
Economic Theory of Railway Location, con-
stitutes about, on the average, between
twenty and twenty-five per cent of
the total operating expenses. It en-
comprises as principal items, labor on
track, new rails, new cross ties, repair
of bridges, buildings, fences, waterworks, etc., of which the chief one is, in any ordinary case, cost of labor for repairs of road bed and track. This item would not be expected to be as directly affected by the tonnage with stub rails and excellent track, as with lighter and poorer construction, and it is in fact to some extent independent of it, probably giving more and more so. But as the labor was less directly influenced by it, the difference between the bicycle and standard gauge systems in the item of track labor would be less, the light bicycle trains would effect a smaller saving in that direction than if the track labor varied directly with the tonnage. The much lighter and narrower track would however make it considerably less, so that, if the road
were supported by electricity, it might be estimated at perhaps one third or one fourth that on standard gauge lines.

If steam locomotives were used, they would have perhaps, as had an effect on that track as the standard gauge locomotives on theirs. It would seem as though there must be some lateral motion or swinging of the engines, above the wheels about a vertical axis, that would bring their flanges against the rail with considerable force at times, as in the styles No. 2 and No. 3 there are only two guide wheels for the whole engine. The action of this lateral force at high speeds would of course result in more or less injury to the road bed.

The weight on the drive of the
first locomotive built was fourteen tons, which would give it considerable tractive force, but this was found to be too heavy for the Coney Island road where it was used, and a lighter engine, No. 2 with only five tons on drive, was substituted. The standard now, No. 3, weighs sixteen tons having 16,000 pounds on each driving wheel, and would seem capable of doing about as much damage to the light track of the bicycle road as the standard gauge engines to their track. For the road operated by steam, then, the item of track labor would not be reduced more than half.

The rails may fairly be taken as lasting the same length of time, though when replaced by new ones the cost would be about one third. The ties would not need replacing.
as often as on a standard gauge road because of the lighter trains and steadier motion. They would probably deteriorate as rapidly, but could be used somewhat longer as the rails would be subjected to less side pressure. New ones would cost about one half as much and the item of cost of new ties would be somewhere about one third or one fourth that on the present road.

The expense due to snow, ice, washouts, etc. would bear about the same relation to the total operating expense as on the standard gauge road. There would be the new expense of maintenance of the overhead structure, which would need regular inspection and repair when necessary. There would be no great difference in the items of repair of bridge...
buildings, fences, water works, etc. The repair of bridges might be less but would not be likely to decrease more than one half; that of buildings, fences, and water works of a steam bicycle road would be no different from any steam road, and for an electric bicycle road would be no less than any standard gauge electric road. Without the danger of sparks from locomotives and need of water supply at short intervals.

For this road, a complete system of interlocking block signals and switches throughout the whole length of the line would be necessary. The danger of collision would be many times increased when running at the high speed, and around the sharp curves proposed, with the
double line of stakes to obstruct the view, especially on curves, and the results would be more disastrous than on a two-rail track. For the shock would be extremely liable to derail the cars, and, once off the track or out of connection with the guide rail, there would be nothing to prevent their overturning, and, as narrow as they are, they would then be easily destroyed even if they had withstood the first shock. The trains would therefore need the rest of protection which might be afforded by such a system as is described in the catalogue, where as a train leaves a block, it cuts off the current thereof until it has passed through and cleared the next block, when the circuit is restored and any following train
can proceed through the first one. This
should be no more expensive to main-
tain than the systems used on other
roads at present. There would be
liability of derangement of the ap-
parative as in any automatic sys-
tem.

Now, for an average, the cost of
labor on track, as gathered from the
sources before mentioned, and from
Poe's Manual, seems to be about
forty-five or fifty percent, the cost
of new rails and ties about thirty-
percent, the percentage due to ties
being greater on some roads, and that
due to rails greater on others, but
the total for both being in each
case not far from thirty percent,
and the cost of bridge repairs about
twelve percent, of total maintenance
of way expenses. Then a reduction as-
sumed in three items of three fourths, two thirds, and one half, respectively;
would be a reduction in main-
tenance of way expenses of about 60 per cent.
The cost of locomotive repairs, which does not exceed ten per cent and generally does not reach that, would not be decreased much, if any. If electricity were the power used, there would be, instead, the expense due to a much greater number of motors and stationary machinery. The engine repairs may be treated like the car repairs and be taken at very nearly the same as on the present standard, gauge lines, for although the cost per car mile would be lower, the total car mileage would be much greater, because of the higher speed, and, in the freight traffic, t-
cause of the smaller cars also increa-

The advocates of this system at-
tach great importance to the very
low rate of fuel consumption ob-
tained in running locomotive No. 2.
They publish the sworn statement
of the coal dealer supplying the
road, that the entire amount of
coal used for the locomotive, hauling
a train one hundred and seventy-
five miles daily for thirty-one days
was 3,1000 pounds. This is about 5.7
pounds of coal per train mile, and
the trains seated one to three hundred
passengers. It is a very small amount
of fuel, one tenth it is said, compar-
ed with what the ordinary locomo-
tive consumes to haul a train of
equal capacity, but is a result of
the very light trains and diminish-
ed resistance. It would alone reduce the operating expenses, on an average, about six or seven per cent, as the cost of fuel, averages about seven or eight per cent of the whole.

This showing of 5.7 pounds per train mile, however, covers only one and three-quarter miles and one month's operation and was made by the company directly interested in the bicycle system. The character of the road and other circumstances may have been exceptionally favorable; and this one trial could not be relied on greatly in place for other lines of any length, where, under different conditions, different results might and undoubtedly would be obtained.

The cost of train wages and service would not be materially different from that of a standard gauge.
road. If the road was operated by electricity, the services of a fireman would not be needed, which would reduce the item of wages about twelve or fifteen per cent, or the operating expense nearly one per cent. The switching and yard expenses for the freight might be increased by the greater number of cars to be handled.

There would, then, according to this estimate be, on the average, a decrease in operating expenses due to maintenance of way of about fourteen per cent, to fuel six per cent, and to trackage wages one per cent, or a total of one fifth to one fourth in the expense of operation in favor of the bicycle road. This would vary as the different items that go to make up the total expense assumed greater or less.
relative importance, depending on the location of the road and the char-
acter and amount of its traffic. The statement is advanced by the company that the cost of opera-
tion would be reduced ten-fold, because the trains are one fifth the weight and of twice the seating ca-
cacity of standard gauge trains. But it is not true, considering the total expense, that, as they assert, it costs ten times as much to haul ten tons as one ton, for much of the expense bears no relation to the tonnage, and even the coal burned by locomotives is not directly propor-
tional to weight or length of train. There are several features of this system that, while they do not result in any loss or gain that can be di-
rectly determined, should be considered.
because of their unfavorable effect in actual operation.

The freight cars are necessarily only one half, or even less, of the width of the standard-gauge cars. While for many classes of freight this would result only in a smaller car load, with others, as carriages, furniture, street cars, machinery, or structural iron work, it would be impossible to ship only in sections, instead of in a completed state as now. This would, of course, be possible but would not be an advance in the business of transportation and would result in added expense and trouble on account of the necessity of assembling the parts at their destination, and putting them together with perhaps poorer facilities than at the point where they were shipped.
With long-distance passenger traffic, it would seem that the narrow space to which passengers would be confined in cars only four feet wide, after being accustomed to travel in cars ten feet wide, would be exceedingly uncomfortable, while the compartment arrangement of the interior would meet with disfavor among many and would prevent free passage from one car to another. Yet it is mentioned as one of the means by which the cars can be lightened to such an extent, while still preserving their strength.

The construction of narrow sleeping cars with either three feet wide and a passage-way only one foot wide is planned, but such accommodations would certainly be insufficient.
especially since many object to the much more ample one afforded at present. The two story cars give a clear inside height of only six and a half feet, which is fairly sufficient. It would probably be said that high speed of the trains shortening greatly the time of the trip would overcome these objections, but still I think that those traveling on these trains would find the ride more disagreeable on account of the small car, even though the motion was more smooth and steady.

The freight cars make no saving over the standard gauge ones in the proportion of non-paying to paying load; for both cars the rates is about one to two. It would apparently be a distinct
disadvantage and an expense to have so many cars to handle, for although they would be lighter, there would, with the same amount of traffic, be three times as many as of the present standard freight car, and this must cause a considerable increase in the expense connected with the yards and the management of the freight traffic.

The construction of a bicycle road for freight business in competition with any existing transportation lines would be unprofitable on account of the impossibility of interchange of cars causing a loss where the freight had to be rechipped, and taking away a large amount of business to the other roads which could...
ship through in bulk. As through sleeping cars from the other roads could be taken, and so a certain amount of passenger traffic would also be lost.

This is indeed recognized by the company, and the standard gauge track acknowledged to be necessary for roads operating through freight and sleeping car, where these innovations would have to be introduced very slowly, if at all, as they would require universal use to be of value. This must, then, be, what does not seem at present to exist, an urgent demand for this system of string proof of its great economy in order to cause any road to make a beginning in its adoption, with all the exper-
live alterations that would be required.

Finally, then, I should say the bicycle railway does seem in some respects to be well adapted to operate new elevated railroads where required in cities and their suburbs.

The plan to adapt already existing elevated or surface roads to operation by means of it, does not seem to give as great improvements over what could be obtained with the present system, as is claimed, and so is not apparently of great value. It does not appear possible to effect as great economy on through long distance lines as it represented, and the bicycle system does not seem suited for such roads.

In the company's descriptive
In the pamphlet, the road is said to be best suited to serve as feeder to trunk lines, for suburban traffic, and for limited express trains on the present roads, and the first two of these are really all it is suited for. The only field to which it is well adapted, and in which it would seem to possess special advantages is, as I have said, in city and suburban rapid transit lines.

As for the reported economical and satisfactory working of the system in actual operation, the absence, or small amount of swaying and oscillation, the exact balancing of the cars, so as to be often uncushioned by the guide rail, the high speed around the sharp curves and up the steep grades.
of the Long Island road, they would all, if supported by personal observation and experience on the road, have great weight in convincing one of the excellence of the system. Without this however, I am led to doubt if these points have not been given more prominence than is merited, to the exclusion of what bad features there may be, by the advocates of the road, and whether in all cases, with the road operated by those not directly interested in the success of the invention, these claims would hold good.