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On the Network of Railroads that Could be Built Today in France

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(Du réseau des chemins de fer tel qu'il pourrait être établi aujourd'hui EN FRANCE)

Michel Chevalier

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Académie des Sciences morales et politiques, 10 and 17 March.

[163] The main lines, in favor of which the opinion of the public and the administration agree, and on which there is virtually no debate other than the significant questions of public and political administration raised by undertaking such a vast system, such as the intermediate places it must pass through, who is to build all or part of it (the state or companies, the Corps of Bridges and Roads, the engineering and artillery officers in the Army). These main lines that have properly been called politically necessary are five in number, precisely:

1. From Paris to the Mediterranean via Lyon and Marseille.
2. From Paris toward England, Belgium and the Rhenish provinces.
[164] 3. From Paris to the Iberian Peninsula via Bordeau and Bayonne, with an extension to Nantes.
4. From Paris to Central Germany, toward Vienna and the Danube, via Strasbourg.
5. From Paris to the sea, via Rouen.

In addition to these five Parisian lines, two additional ones must be added, one from the Gulf of Gascony toward the Mediterranean or from Bordeaux to Marseille, the other from the Mediterranean to the North Sea, or from Marseille to the Rhine. Adjoining the Mediterranean, this would be, if you would excuse the expression, an artificial Danube as useful to Germany, and to the North, as the Danube is with its link to the Black Sea. The railroad from the Mediterranean to the North Sea is not truly possible except through France. To go via Genoa, Venice or Trieste to Hamburg, you would have to create a passage across a chain of mountains before which artifice must decline. You encounter neither the Tyrolean Alps nor the Rhaetic Alps, nor elevations of four thousand meters. The sole barrier to be overcome is an extension of the Jura only 350 meters high, which has already been crossed by the Rhône-Rhine Canal, and which will easily be overcome again by a railroad.

To open this link requires a railroad departing Strasbourg toward Lyon, joining the line from Paris to Marseille.[1]

If steam navigation in the Atlantic develops as the daring beginnings indicate,[2] it will [165] become necessary to build another line toward our westernmost port, namely Brest, since Brest will become the point of departure for the areas of the New World with which we shall have greatly-multiplied relations, but the hypothesis on which the building of a line to Brest is as yet so uncertain that it is exclusively the domain of political speculation.

It is hard to say exactly what the total length of this system would be, but it can be estimated at 1024 leagues, specifically:

Mediterranean route		220 leagues
Route from England and Belgium or the North		
Paris to Calais, via Lille	87	
Extension to the Belgian frontier toward Ghent, via Lille	4	
Branch to Valenciennes, and extending to the Belgian frontier, toward Mons and Brussels	18	
Total		100
Route to Spain, via Bordeaux and Bayonne	200	
Branch from Nantes	47	
Total		247
Paris to Central Germany, via Strasbourg		116
Paris to the sea, using a part of the Nord railroad		50
Mediterranean to the North Sea:		
Saint Symphorien via Strasbourg and Basel		148
Gascony to the Mediterranean:		
Bordeaux to Beauclaire		134
Total		1024 leagues

[1] The system of railroads that the administration plans now, described in the law presented on 15 February, differs from this plan only in one additional line, from Paris to Toulouse via the center of France. This line would be hard to build and of dubious utility.

[2] In England they are building three steamboats to serve New York and the English ports of London, Liverpool and Bristol. The departure of one from London was on 28 March.

Public opinion in England is occupied with the revolution that would take place among the various national ports if steam navigation comes to function regularly and economically from one side of the Atlantic to the other. It appears obvious to the most competent men that the ports on the western coast of Ireland will have a marked advantage over the Saint George Channel separating Ireland from Great Britain, and that, for example, some little Irish port that is obscure today, such as that of Valentia, would perhaps eclipse Liverpool itself.

Our excellent engineers have studied a system of eleven hundred leagues to the last detail at an average of 900,000 francs per league. This estimate is inadmissible if you adopt the mode of construction proposed by the engineers and adopted by the administration of Bridges and Roads, because this system is copied from the English, and despite all preconditions in the estimate, in England it would demand about two millions per league. This is because, if on the other side of the Channel railroads cost two million we cannot understand how in France, on a soil ordinarily more varied, with the same assumptions on pitches, radii of curves, and two track construction, they would cost less than half as much. [166] Assuming that our engineers applied themselves rigorously to build in a simple style and not monumentally, it is neither impossible nor improbable that, even while paying more for iron than our models in England, they would be able to restrict expenditures to 1,500,000 francs, for example; but it would imprudent to expect a larger reduction, which was promised in the estimates. The reputation for truthfulness of estimates is as proverbial as that for bulletins, and what happens every day before our own eyes shows that the public is not wrong.

At 1,500,000 francs per league, the total cost of the system of 1024 leagues would be 1,536,000,000 francs.

This sum is more than considerable; it is shocking. There are many inconveniences to which the government, giving in to a praiseworthy desire to satisfy public impatience that wishes to enjoy the railroads, seeks to gain a brief delay, or, what amounts to the same thing, for a good management of public wealth, to have the railroads built by the companies. To apply such a mass of funds from the other uses to which industry gives to the national wealth would plunge the country into a commercial crash similar to that which the Americans were recently victims. In matters of capital, even if endowed with some elasticity, every shift that is not managed is dangerous. Here as well is seen that law of rational mechanics that every brutal shock leads to a loss of vital forces.

One of the ways to avoid this difficulty is to reduce the cost of first introduction of railroads by adopting another system of construction. There is a place to ask to what extent we are required scrupulously to adopt English ways, we who have a territory much larger than our neighbors across the Channel, so that our lines are much longer; we who dispose of much less capital; we who have to transport a less-rich populace, and thus are unable to pay for seats to cover the costs of their creation along with a certain profit. Wouldn't that incline us toward the American system of construction, a system that, as the supreme arbiter of this [167] world, experience, has no fault but covering (at a considerably slower rate) the current costs of operation, and at a third or a quarter lower speed, but which has the solid advantage of costing eight times less than the English system?

Placed, in terms of the extent of territory and abundance of capital, between England and the United States, shouldn't we hold ourselves between them as far as the mode of building our railroads, at least if we do not wish to experiment with the public fortune after having exhausted our efforts on forms of governance, or that, in a surfeit of humiliation, we do not consent to open rapid communications across our France with a slowness that will permit only our grandchildren to appreciate the benefit?

The excessive cost that the building of railroads entails, if we choose the system that the Administration of Bridges and Roads prefer, holding to absolute rules that our

engineers have imposed on themselves, include three of them that are truly onerous. These are:

1) A *maximum* pitch that is a tenth or even a twentieth of the maximum of the *maximum* set for ordinary roads. This creates the necessity to fill valleys and tear down mountains.

2) A very reduced minimum for the radius of a curve in turns. This obliges not to take any account of natural difficulties of the soil, and once again to fill valleys and tear down mountains to conform to a certain limit to contours of terrain and its inequalities.

3) The establishment of double tracks along the entire length of the railroad, with one exclusively for trains in one direction, and the other for the opposite direction.

It is good to examine:

1) If we must impose a maximum of three or three and a half thousands pitch.

2) If we must forbid radii of curve less than a thousand meters.

3) If main lines always have to have two [168] tracks, and if it would be better if they reduced themselves to only one for works of art, especially bridges, establishing sidings from place to place.

I do not pretend to determine to what extent the precision of the rules extend for our engineers. I am reduced to inquiring how these rules can be rigorously maintained in all cases; like sacramental acts, you grasp them while subjecting them not just to mathematical, but also commercial, financial, and administrative standards. To be sure, a railroad where it would be possible to observe them would be better than another where they were violated. But two railroads, each of a hundred leagues, for example, even when presenting some imperfections in terms of pitches or curves at three points, seem to me to be better than a single railroad of a hundred leagues where one is religiously in keeping with the limits of an abstract theory. We profoundly respect the mathematical sciences; let us consult them, it is an excellent touch-stone, but mathematics cannot pretend either to govern or to administer the state alone, and experience, at any moment, is worth all the A + B in the world. So if experience demonstrates that public safety has nothing to fear from pitches of five thousandth, and that over short intervals one may admit seven thousandth and more;[3] if experience shows that one may easily guide locomotives through curves of which the radius is no more than half, a quarter or even a tenth of the *minimum*[4] recommended by the general council of Bridges and Roads, it seems to me [169] that the profane public could, without losing the regards owed to the knowledge of our engineers, appeal their decision. The public economy also is within its rights to

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[3] One frequently sees on American railroads, served by locomotives, pitches of 40 to 50 feet per English mile (7 $^{1}/_{2}$ to 9 $^{4}/_{10}$ thousandth). In some cases, they have established double pitches where service was by locomotive. On the Liverpool Railroad, there is a pitch of 11 $^{4}/_{10}$ served by locomotive. On the same railroad, Monsieur Minard mentions a pitch up to 22 thousandth, but it is served by a fixed engine and is thus treated as an inclined plane.

[4] On most American railroads, curves of as little as 1000 feet (300 meters)in radius are admitted. On the Baltimore & Ohio Railroad, there are many curves of 400 to 600 English feet (120 to 180 meters). There is even one of less than 500 feet (90 meters). Yet one uses locomotives on this railroad; it has been necessary to seek some special arrangements to remedy all danger. The recent experiences of Monsieur Laignel have demonstrated that, by a simple and ingenious combination, it is possible to sustain high speed, of 9 leagues and hour for example, on curves of a 500 meter radius.

reclaim its deliberative voice in the matter of railroads, as in all circumstances where it deals with great enterprises of positive interest; and I strongly doubt that it would approve of the reasoning of our engineers about capital.[5]

So far as the doubling of the tracks, I believe this is a subject on which, without being myself an eminent member of the Academy of Sciences, one could form an enlightened opinion. On this matter, every sensible person is competent, and I will listen more happily to the views of a postal inspector or the director of a message service than to the best-versed theorist in infinitessimal calculations. Everyone would agree that two tracks are necessary to any railroad terminating in Paris within a radius of ten or fifteen leagues, because in this case an arrival and departure each hour or even each half-hour, and, let's say that with a single track on the Saint-Germain Railroad, one would have a service more than adequately regular, [170] and that no accident would trouble even on inauguration days, even at the beginning, when all the employees were novices and not yet familiar with all their duties. But between Paris and Lyon, for example, there are two departures separated from one another by five or six hours. Between New York and Philadelphia, towns of 250 thousand souls, in this country where people do not stay in one place, and of two persons one is underway. On each point of this railroad, there are only four trains of carriages with passengers. Add to that one train in each direction for merchandise, the total number of trains would be only six. Thus, on a single track, it would be easy to discover in every case their hour of departure and the times and stations when they would meet one another. It would be possible to assure passengers of a trip almost without interruption without their running any risk and without any train meeting another one coming the other way. The organization of the service would be very easy in this way if, from place to place, especially near large towns, the track were doubled for a length of two or three leagues.

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[5] Concerning estimates, it often happens that one seizes on reasoning such as this: "If you pay attention to sparing capital, you could evaluate a particular length of the railroad with a cost of 1,200,000 francs instead of 1,500,000, but then the cost of traction will be increased annually by 20,000 francs. By paying once and for all 300,000 francs for the first construction, you save an annual cost of 20,000 francs. So by agreeing to add these 300,000 francs to the original cost, you have invested 300,000 francs at 6 $^{2}/_{3}$ %, which is an excellent investment hard to refuse." This manner of reasoning is precise when it concerns small amounts, but it ceases to work when it concerns 3 or 400,000 francs, because it assumes that there is in the country an infinite amount of capital that it is possible to exploit at will, as if it were the ocean, without disturbing it. So that is an entirely gratuitous hypothesis. The quantity of capital one may draw from the financial market without inconvenience is limited in every country; it is particularly so where, as in France, the institutions of credit barely exist and where the organization of capital is defective.

Further, the increase of the running cost of a railroad you concede in adopting pitches above 3 to even 5 thousandths, and curves below 1000 meters or even 500 meters in radius, would be proportionally much above what I allowed for in the example above. With curves of a short radius you are simply restrained to slowing your train during the brief period you are passing through the curves; it appears that even with Monsieur Laignet's system, you can avoid this precaution. With pitches of more than 5 thousandths that are continued beyond a certain length, the additional cost is reduced, when you are trying to maintain the same speed, by using a supplementary engine that is attached to the train to mount the ramp, just as wagoneers add an extra horse when they have a slope to overcome. There are even more combinations for pulling too involved to detail here that would reduce costs considerably. Such were the measures I saw recommended to the company of the New York to Lake Erie Railroad by a commission of engineers consisting of messrs. M[oncure] Robinson of Philadelphia, B. Wright of New York and J. Knight of Baltimore.

With two passenger trains in each direction between Paris and Marseille, one would not have to endure only two moments of stopping, of which the duration would not be more than a half-hour; thus only an hour would be added to the voyage. The freight train would not slow the passengers down, because one would leave the path open by holding it at a siding station conveniently placed between the ends of the route. Even when the delays experienced was some hours in length, inconvenience would not result. By means of these stations, one could add another train for passengers coming and going between the extreme ends. In a word, although it is to be hoped that a double track would eventually exist on all main lines, but one could tolerated a single track for half or two-thirds of the length without difficulty or danger to the public Doesn't the experience of the United States, where they travel more than here, and that of Belgium, which is the most populated part of the European continent, justify this hope?

[Chevalier goes on to sketch an interim transportation system for France that would combine railroads with steamboats. He uses American experiences with coordinating railroads and steamboats, such as from Long Island to New York City and on the Hudson. He appends time and distance tables for the whole system.]

P. 172 — interim use of rail and boat links, using steamboats.
P. 187, note — list of transfer times from train to boat, usually half an hour, shown by the route from New York City to Boston, Philadelphia to Baltimore, etc.
P. 191 — estimates of seat prices, which could be reduced over time.
P. 195 ff. — total schedule and prices for each line in the system.