Spatial Competition, Strategic Entry Responses, and the North Dakota Railroad War of 1905[*]

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Abstract

The North Dakota Railroad War of 1905, which pitted a potential entrant (the Soo Line) against an established monopolist incumbent (the Great Northern Railway), offers a lucid empirical example of strategic behavior, and in particular the potential for entry deterrence through product proliferation. I use detailed geographic data and historical records to examine the profitability of both the incumbent's and entrant's potential and chosen strategies. I find that the incumbent could have likely profitably deterred entry. It did not, however, waiting instead to respond only once the entrant began building. This simultaneous entry potentially led to over expansion in the market. I investigate whether the chosen strategies may have ultimately ended up being both unprofitable for the firms involved as well as, potentially, socially wasteful.

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I. Introduction

This paper analyzes the economics underlying one of the most empirically vivid examples of spatial strategic competition between an incumbent firm and a potential entrant into its market, the Soo Line Railroad's plan to build its Wheat Line (a line connecting two of its major lines) through formerly monopoly territory of the Great Northern Railway. This took place in northern North Dakota and Minnesota in the first decade of the 20th century.

A large theory literature has characterized many forms of potential strategic behavior among incumbent firms and potential entrants into a market.[1] Depending on conditions, incumbents may have an incentive to respond pre-emptively to threatened entry or in a particular manner once entry has occurred. Regardless of the particular timing, the incumbent's intent with such strategic actions is to favorably shape the structure of market competition.[2] The (potential) entrant, in turn, faces a decision as to how to best respond to the incumbent's behavior, and indeed the incumbent's action likely builds expectations of this reaction into their initial strategy.

When such strategic interactions occur in differentiated product markets, a spatial element is typically present, whether in product or physical space. Product variety and placement are therefore key strategic choices for the firms, interacting not just with consumer tastes and the firms' production costs, but the expected responses of their competitors as well.

[1] Just a sampling of this large literature includes Schmalensee (1978); Dixit (1979); Kreps and Wilson (1982); Milgrom and Roberts (1982); Aghion and Bolton (1987); Klemperer (1987); Benkard (2004); Ellison and Ellison (2011); and Gedge, Roberts, and Sweeting (2020).

[2] When using the term "strategic behavior" and its variants here, I have in mind a definition such as the one offered in Khemani and Shapiro (1993): "Actions taken by firms which are intended to influence the market environment in which they compete…[this includes] non-cooperative actions to raise the firm's profits at the expense of rivals." In other words, they are choices of firms not made as a direct best response to competitors' actions (such as prices in Bertrand oligopoly or quantities in Cournot), but rather made to influence a state variable that influences current or future payoffs, perhaps directly or in turn through firms' best responses to those state variables.

Schmalensee (1978) formalized the notion of a particular form of this type of strategic interaction, product proliferation. The argument is that a competitive threat might induce incumbents to produce a greater variety of product types than they would otherwise. The motive is that proliferating products "fills up the product space," reducing a (potential) entrant's residual demand and expected profits. If successful, this strategy can preserve incumbent market power, regaining through higher markups the extra costs associated with the incumbent producing additional products. Schmalensee (1978) cited the ready-to-eat cereal market as an example of a market equilibrium driven by such considerations and actions.

There has been some empirically oriented research on strategic behavior in differentiated product markets.[3] However, this depth and scope of this literature has been inherently limited by difficulties in observing potential entrants and accurately characterizing the product space. This paper explores incumbent-entrant strategic interactions in a market where these limitations are largely absent. Indeed, I argue the case study explored here may one of the clearest empirical examples of such competition. Yet while the episode has earned mention from a handful of historians and geographers, it has not to my knowledge been previously explored by economists or business scholars. This paper aims to change that, drawing out a full economic picture of spatial strategic competition between an incumbent firm and a potential entrant into its market.

1. The Market

The specific setting is the North Dakota Railroad War of 1905. The war pitted the incumbent Great Northern Railway (henceforth GN) against the entrant Minneapolis, St. Paul,

[3] Examples of empirical work on strategic behavior more generally include Benkard (2004); Goolsbee and Syverson (2008); Ellison and Ellison (2011); Wendling and Tenn (2014); and Gedge, Roberts, and Sweeting (2020). Examples with a particular focus on product proliferation strategies are Connor (1981); Shaw (1982); Bokhari and Yan (2020); and de Haas, Herold, and Schäfer (2022).

and Sault Ste. Marie Railroad (aka and henceforth the Soo). Prior to 1905, the GN held a virtual monopoly over an area of northeastern North Dakota and far northwestern Minnesota that extended roughly 60 miles north-to-south and 250 miles east-to-west. (This is just a bit smaller than the combined area of Vermont and New Hampshire.) The area was bounded on the north by the Canadian border, on the south by the GN's main line, and on the east and west by two of the Soo's main lines.

Figure 1a shows GN's route map circa 1912. GN's main line ran in a generally east-west direction, heading from the Twin Cities to Fargo, then north to Grand Forks, then across northern North Dakota, Montana, Idaho, and central Washington, until reaching Seattle and extending down the coast to Portland. (The cutoff between Fargo and Minot, ND was not built until 1912, after the Railroad War.)

Inspection of the figure reveals a much higher concentration of branch lines extending north of the main line in North Dakota than in Montana, Idaho, or Washington. Indeed, the GN had 13 northern branches in the 310-mile span of North Dakota, while it only had a total of 10 branches across the remaining 850 miles between the eastern Montana border and the Pacific. This 3.5-fold difference in branch density is a motivating fact for our analysis. Why did GN build so many branch lines in this area?

Some of the difference in branch density reflects differences in demand on either side of the ND-MT border. North Dakota was much more cash-crop intensive (mostly wheat, but also other cereals like oats) than the states further west, and railroads were the primary method used to send crops to market. As we will see, however, this difference in demand was handled by the monopolist GN with fewer branches than those shown in Figure 1a. The full density of branches

resulted from the Railroad War; specifically, GN's track-building binge in response to the Soo's planned entry into GN's monopoly territory.

Figure 1a adds the relevant Soo lines to the map. The solid red lines bounded the GN's monopoly area on the east and west. These were primary lines for the Soo and connected at the Canadian border with the Canadian Pacific Railroad, which had both a partnership with and substantial ownership interest in the Soo. The Soo primarily used the lines to carry grain from Canada's Prairie Provinces to mills in Minneapolis and export terminals in Duluth, MN.

In 1904, the Soo devised a plan to connect its two major lines with a railroad that would run parallel to and roughly 25 miles north of the GN main line. This line, which the Soo called the Wheat Line given the expected source of much of the line's revenues, would run through the heart of the region where the GN had faced no competition. The approximate route is shown by the red dashed line in Figure 1b.

It was this plan for the Soo to enter the northern North Dakota market formerly (nearly) monopolized by the GN, and the GN's response to the plan—the so-called North Dakota Railroad War of 1905—that I investigate in detail in this paper.

1.1. Advantages of This Setting for Studying Strategic Behavior

This case study holds several advantages for better understanding strategic behavior in spatial markets.

First, the identities of the competing firms are well known. Potential entrants can sometimes be difficult to identify, as most data is collected only for firms active in a market. Here, there is no doubt that the Soo is the only potential entrant. For reasons described below, the only other two railroads operating in the area were minor, non-strategic players.

A second benefit is the relatively rich set of historical documents involving this market and the companies that competed within it. These include corporate financials, correspondence, and elements of strategic competitive planning. This allows me to understand many of the market's institutional details and the information contemporaneously available to the decision makers.

Third, as will be discussed further below, the primary form of product differentiation in the market is spatial. Demand for the railroads' services was closely connected to the catchment area of their lines. I have access to detailed location data for all of the lines that the railroads operated and the towns that lay along them, so I can compute the catchment areas—both existing in the market and for hypothetical line-building scenarios. Further emphasizing the primacy of spatial competition in this setting, I detail below evidence that the railroads viewed themselves as undifferentiated competitors once they conditioned on location.

2. The Situation in 1904

I now zoom in on the monopoly area, between the Soo's lines, south of the U.S.-Canada border, and north of the GN's main line. Figure 2a shows the situation in 1904 in this area.[4] Because all strategic interaction will occur within these bounds, the figure shows only the railroads within them. Some of the plotted railroads extend beyond the plot, and other railroads, especially those south of the GN main line, are excluded for clarity.

2.1. The Incumbent

[4] This map and all that follow are plotted with GIS and are accurate to a matter of a few dozen yards. The top of the map is the U.S.-Canada border. The Red River of the North, which forms the boundary between North Dakota and Minnesota, is also shown for reference.

The GN was the dominant incumbent in the study area and much of northern North Dakota, Montana, Idaho, and central Washington more generally. It offered service both along its main line and on multiple branch lines extended north from its main line. (In the study area, north-going branches often angled to the northwest). Its president and largest owner, James J. Hill, was a well known figure and leader in the railroad industry at the time. As I describe in more detail below, I use the Great Northern's quasi-monopoly status in the study area to conduct some of my key analyses.

2.2. The Entrant

The Soo was a persistent competitor of the GN throughout the railroads' service areas. While the presidents of the two companies lived in the same city and were personally friendly, they were dogged competitors in the market. There is no evidence in the historical record that they colluded in the product market.

The Soo planned the Wheat Line to run roughly parallel to and about 25 miles north of the GN's main line, connecting to the Soo's lines on either side. The Soo attempted to keep the Wheat Line's planning surreptitious. The survey crews who initially laid out the route traveled under false names and pretenses. The GN nevertheless received word about the plan early on. In fact, the GN sent their own agents to follow a day or two behind the incognito Soo survey crews, pumping locals for information about where the survey crews went and what they did.

The Soo eventually settled on a Wheat Line route that would connect Thief River Falls, MN on their eastern line to Kenmare, ND on their western line. Most of the Wheat Line would run directly east-west, though it would turn to a northwest-southeast heading between two of GN's branches and continue in that direction for 45 miles before turning east-west again. In

addition, there would be a single branch to the northwest off the line. This branch would initially be built about 21 miles to newly founded town of Armourdale, located about 9 miles from the Canadian border. The original plan was to later extend the branch north to meet a Canadian Pacific line to be built to the border. However, this international extension never was built. Figure 2b shows the actual location of the Wheat Line as built, laid upon the 1904 status quo.

2.3.The Others

Besides the Soo's lines that bounded the study area, only two other railroads are present in it, the Northern Pacific (NP) and the Farmers Grain and Shipping (FGS). The NP had a single branch passing through the easternmost portion of the study area. The NP had been rescued from bankruptcy in the early 1890s by J.P. Morgan and the GN's James J. Hill. The historical record makes clear that as a result, while the NP was not closely controlled by the GN, it took pains not to aggressively compete against the GN. (The NP was considerably more built out in southern North Dakota, where the GN's presence was more limited. All its other lines ran south of the GN main line.) I treat the NP as an exogenous but non-strategic competitor expected to take no future action in the study area.

The other railroad in the study area is the Farmers Grain and Shipping Railroad (FGS). The FGS was a 23-mile-long short road running due north from the GN's main line in Devils Lake, ND. It was founded by a set of area farmers and businesspeople unhappy with GN's refusal to build a branch in the area. The presence of railroad customers unhappy with GN's branch network—unhappy enough in this case to actually build a railroad of their own—is a convenient fact that I will use to infer line-building costs below. In the analysis of the pre-Railroad-War market, I treat the FGS like the NP: a passive competitor with no further appetite

for strategic competition with the GN. Regardless of the intents of their owners, the FGS was tightly capitalized and unlikely to be able to aggressively expand even if it wanted to. As we will see, however, unlike the NP, once the Soo planned to build the Wheat Line the GN did not view the FGS completely as a given entity.

3. Analysis of Profitability of Soo Entry and GN Response

To understand the GN and Soo's optimal strategies, I need to estimate the expected profitability of any strategies they might consider. The key to my analysis is the fact that GN was essentially a monopolist in the study area before 1905. Supposing the GN's route network was profit-maximizing for a monopolist, then additional lines the GN *could have built*, but did not, were unprofitable. If I assume further that the GN and Soo had similar demand and cost structures, I can use this fact to estimate the Soo's expected profitability of the Wheat Line.

3.1. Computing Railroads' Catchment Areas

Railroad product differentiation in this market was primarily spatial. Distance was the most important factor in determining where farmers would take their grain to market, and for that matter where they would purchase products and merchandise typically brought to the area by the railroad. Hauling grain was expensive, and proximity would typically override any other considerations.

Farmers could not simply pull their cart alongside the railroad and expect a train to stop to load their grain. Railroads relied on loading and unloading at collection points. That is, towns. In this part of the country at the time, most areas were too sparsely populated to have a sufficient

density of existing settlements, so railroads simply founded towns on their lines where they were needed (Hudson, 1980).

The railroads did not own much of the land in the towns themselves, other than what was necessary for depots, warehouses, and maintenance facilities. Instead, they worked with private developers who would plan the town and sell housing and commercial lots to homeowners and businesses.

One business present in every town was a grain elevator (often, there were multiple). Elevators, which were owned and operated by firms that specialized in this business, bought grain from farmers and stored it until they chose to load it onto trains to send to market. Thus a railroad's catchment area was actually the combined catchment areas of the towns along it, because they were the relevant nodes of commerce. Railroads realized this and typically spaced the towns they founded sufficiently closely along a line (a between-town distance of about 7 miles was common) so as to not have commercially dead stretches along the line, while at the same time not simply cannibalizing demand from neighboring towns.

To compute railroads' catchment areas, I use Voronoi diagrams of the towns along them. A Voronoi diagram, for any given set of points on a plane, partitions the plane into regions closest to each point. Here, the points are the towns' latitude and longitudes. I obtained these from the US Census Bureau when available. For the many towns in the study area that never incorporated (and hence not covered separately by the Census) or are now ghost towns, I used satellite pictures from Google Maps to identify the most likely location of the town.[5] The area within the plane closest to each town is contained in the town's Voronoi polygon.

[5] I place the town at the latitude and longitude where I determined was the most likely location of the town's elevator (or at least one of them). It is easy on satellite pictures to spot railroads, even abandoned ones, as the railbed sticks out among the surrounding terrain. Elevators were always on railroad sidings, so this pins down one dimension of the town's location. The location of the town/elevator along the line is typically revealed by the

Figure 3a shows all towns on the railroads in the study area as well as the corresponding Voronoi diagram. The Voronoi polygons are shaded according to the railroad the town sat upon: gray for GN towns, red for Soo towns, orange for towns on the NP, and blue for FGS towns. Towns situated on two railroads have combined shading of their polygons. I assume each railroad captures half of the traffic in those polygons. This even split is supported by the views of the firms at the time; when the Soo estimated the Wheat Line's catchment area, it assumed an even split of traffic in contested areas.

For a town's Voronoi polygon to reflect its catchment area accurately, travel costs need to be uniform across the entire area, so that a given distance has the same travel cost regardless of location. In other words, a Voronoi diagram assumes a flat, featureless plane. Fortunately, North Dakota—at least this part of it—is a flat, featureless plane (plain).[6]

As seen in Figure 3a, Voronoi diagrams partition the entire plane into catchment areas. This poses awkwardness in two instances. First, for towns near the edges of the study area, the Voronoi polygons arbitrarily continue to and stop at the area boundary, and moreover, any towns outside the study area are ignored when constructing catchment areas. These elements of arbitrariness have no practical effect on the analyses here, however, because computations of catchment areas involve catchment area *changes*. Given that all changes occur within the boundaries of the Soo's east and west main lines and the GN's main line, the arbitrary elements of the "edge town" polygons are differenced away.[7]

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presence of streets laid out by blocks (even if these streets are largely abandoned) and other clues like remaining homes/buildings, ditches, and so on.

[6] The exceptions to this would be unfordable bodies of water that would need to be navigated using the nearest bridge, and the Turtle Mountains. For the former, none of the rivers in the study area besides the Red River are major, which I treat by not allowing Voronoi polygons to cross it. As to the latter, as I describe below, the Turtle Mountains were not agriculturally active and no railroads passed through them, making the issue moot.

[7] The bounding of some towns' catchment areas at the Canadian border is consonant with reality. While customs agents were occasionally known to look the other way when Canadian farmers decided to carry grain across the

The second instance involves towns in the interior of the study area but far enough away from neighboring towns for their catchment areas to extend beyond a distance a farmer could haul grain economically. Farmers' practical limits of carriage were known to the railroads, which also offers me a treatment for the issue. Specifically, the Soo assumed its catchment area for the Wheat Line would extend no further than 9 miles from the line. Consistent with its aforementioned presumption of symmetry of it and its competitor, it assumed the same thing for the GN's catchment area of the GN branch lines that it crossed. Based on this, I construct actual catchment areas for towns as the intersection of their Voronoi polygon and a circle centered on the town with a 9-mile radius. I plot in Figure 3b these adjusted catchment areas, which are the ones used in the calculation below.

3.2. Computing the Wheat Line's Catchment Area

Figure 4a shows the catchment area of the Wheat Line as proposed and built, keeping the GN's lines as they were in 1904; i.e., as if GN never responded to the Soo's entry. Table 1 shows the changes in the four railroads' catchment areas under this entry scenario.

Table 1. Catchment Area Changes If Soo Builds Wheat Line without GN Response

Railroad	Change in Catchment Area (Square Miles)
GN	–833
Soo	3214
NP	–21
FGS	–12

border for sale, such cases were not common in practice. Nor was it common for U.S. farmers to carry their grain to Canada.

The Soo would increase its catchment area by just over 3200 square miles by building the Wheat Line. About a fourth of this would come at the expense of the GN. Territories taken from the NP and FGS are much smaller.

Interestingly, before embarking on the project, the Soo estimated the catchment area of the Wheat Line by roughing out a route. As noted above, it assumed a catchment area of 9 miles on either side of the line, and that it would evenly split areas when it crossed a competitor's line. The outcome of this calculation was 1.99 million acres. Given 640 acres in a square mile, my calculation here implies a Wheat Line catchment area of 2.06 million acres, almost identical to the Soo's number.

3.3. Estimating Railroad Profitability Parameters

To analyze the profitability of potential strategic decisions, I need an estimate of the profitability of extending a railroad network. To do so, I use the fact that GN was effectively a monopolist in the area through 1904. If GN's 1904 route network were profit-maximizing given that it was and expected to remain a monopolist for the foreseeable future, I can use the fact that there were lines it didn't build before the Wheat Line, but did build after, to estimate profitability.

The historical record is consistent with GN believing it had built out the profit-maximizing monopoly route map before 1905. There were no signs it viewed itself as overbuilt. It had not abandoned any lines in the area, nor was there any consideration of such an idea in the historical record. Perhaps more relevant, the GN did not view itself as *underbuilt*, either. It had no plans to expand. This is not due to an utter lack of demand in the regions between its branches. GN corporate records contain multiple letters (sometimes signed by James J. Hill

himself) responding to petitions from farmers and businesspeople in an area for the GN to build a branch line (Hudson, 1980). Hill and the GN turned these down uniformly, with an explanation of the unprofitability of such an extension (and sometimes a complaint about the strictures of the state's regulatory authorities). Indeed, as mentioned above, the creation of the FGS itself is evidence of the same reluctance to expand in the face of latent demand. Faced with GN's unwillingness to build a branch north from Devils Lake, the FGS founders built it themselves.

Of course, there are in principle an infinite number of branches that the GN could have built, but did not. The question is which ones of this counterfactual set are most informative about profitability. I have some clear guidance here. When the Soo did start to build the Wheat Line, the GN responded simultaneously with an aggressive expansion involving two entirely new branches, the extensions of two others, the purchase and extension of the FGS, and founding new towns on existing lines. Figure 4b adds these new and extended lines and towns and their corresponding catchment areas to the study area map.

The GN could have undertaken all or any subset of these responses before the Wheat Line, but chose not to. Under my assumptions, this implies they were unprofitable for a monopolist unconcerned about entry, as was the case before the Soo hatched its plans in 1904. I use these unbuilt-until-Soo-entry lines to learn about the expected profitability of building railroad branches.

My calculation works as follows. For each of these unbuilt-until-Soo-entry lines separately, I compute the GN's increase in catchment area had it built the line under the 1904 (pre-Wheat Line) configuration.[8] This catchment area would deliver to the GN a present

[8] Note that the catchment areas in Figure 4b reflect outcomes as actually built in 1905, that is, when the GN did its building spree simultaneously with the Soo's construction of the Wheat Line. For my purposes here, however, I estimate their catchment areas in absence of the Wheat Line, as this is what would have determined their profitability within the monopoly GN.

discounted value of operating margin. I specify a line-building cost function and then use the unprofitability condition to estimate the cost function's parameters. I thus obtain an estimate of profitability for any generic line that I can use to pin down the expected profitability of the GN and Soo's strategic decisions (the latter under the assumption that both railroads had similar cost structures).

Specifically, I assume the profit from building a branch line *l* of length l_l that gains catchment area A_l is given by

$$\pi_l = A_l \cdot PDVmargin - c_1 \cdot l_l - f_l \qquad (1)$$

where *PDVmargin* is the present discounted value of the railroad's operating margin per unit of the catchment area. I posit this margin is constant everywhere along the line. The parameter c_1 captures the per-unit-length cost of building the branch line, and f_l is the fixed cost of building the branch.

Suppose $f_l = f + \epsilon_l$; that is, the fixed costs of building or extending a particular branch equal a common component f and a mean-zero idiosyncratic component ϵ_l. Furthermore, suppose the costs of building the line are just high enough to make it unprofitable to do so; i.e., $\pi_l = 0$. Then we can rewrite (1) as

$$A_l \cdot PDVmargin = c_1 \cdot l_l + f + \epsilon_l \qquad (2)$$

To use (2) in the form as written, I would have to take a stand on the value of *PDVmargin*. However, that is not necessary. Because it is a constant, I can divide through (2) by *PDVmargin* to obtain my regression specification:

$$A_l = \frac{f}{PDVmargin} + \frac{c_1}{PDVmargin} \cdot l_l + \varepsilon_l \qquad (3)$$

Thus I can regress the catchment area of a line on its length and obtain the two cost parameters c_1 and f, up to a multiplicative constant. Given the identity of that constant, the cost parameters are effectively in units of the present value of operating margin per unit area.

The assumed cost structure implies the average cost of building or extending a branch line falls with length. This raises the question of what might limit branch length. There are two factors at work in the study area that limit branch length. One are the Turtle Mountains, a forested area of rolling hills roughly 40 miles east to west, straddling the central North Dakota-Manitoba border. The geologic exception to the flat plains around them, the Turtle Mountains were not friendly to either farming or building railroads. Any branch that approached them stopped before entering. The second and more broadly applicable is the Canadian border. While the GN had existing connections with Canadian railways in 1904, it viewed additional connections as inordinately costly. Thus, even with falling average costs, rail branch lines would stop several miles short of the Canadian border (the catchment area of the town on the line's terminus would of course extend to the border).

Table 2 shows the estimates of the cost parameters from specification (3). It shows estimates for two samples. One treats the FGS acquisition and its extension as two separate projects, each with its own fixed cost. The other treats the combination as a single project. The point estimates are not vastly different across the samples, though somewhat paradoxically, treating the acquisition and extension as a single project (which reduces the sample from 6 to 5 observations) actually yields more precise estimates.

The estimated fixed cost is roughly the present value of operating margin of 40-60 square miles. The per-mile cost is about 10 square miles' of the present value of operating margin. The fact that the latter value is less than 18 square miles of margin is reassuring, as under the Soo's 9-

mile assumed catchment area limit, extending a branch one mile would at most increase its catchment area by 18 square miles. Any cost estimate greater than that would imply the variable profit of building anything would be negative.

Table 2. Estimated Railroad Building Cost Parameters

	FGS and Extension Separated	FGS and Extension Joint
f (Fixed cost)	60.1	38.0
	(40.6)	(9.34)
c_1 (per-mile cost)	9.96	10.9
	(1.22)	(0.23)
N	6	5
Estimated Wheat Line Cost (mi^2 of operating margin)	3170	3410

3.4. Estimating Wheat Line Profitability

Cost parameters in hand, I can now estimate the expected profitability of the Wheat Line, under the presumption that the Soo has a similar demand and cost structure to the GN. As noted above, this is consistent with the Soo's own views, as it assumed demand in shared territory would be split evenly.

The Wheat Line as proposed had 306 miles of track. I multiply this by the estimated per-mile cost c_1. For fixed cost *f*, I assume the Soo pays it twice, as the Wheat Line connects two main lines. Further, when the Soo constructed it, the railroad sent separate crews to each end and had them build towards one another and meet in the middle. I presume this from-both-ends-construction involves replicating the fixed cost across two efforts. (I do not assume a third fixed was required to build the Armourdale extension, though it is straightforward enough to add that cost to the estimates below.)

Based on this underlying structure, the total estimated cost of the Wheat Line using each sample's cost estimates is at the bottom of Table 2. The two values are reasonably close, with the estimate assuming the FGS acquisition and its extension are separate projects yielding an estimated total cost of the Wheat Line equal to the present value of the operating margin from 3170 square miles. The value estimated using parameters from the other sample is 3410 square miles.

It is very interesting to compare these numbers to our above estimate of the Soo's gain in catchment area from the Wheat Line, 3214 square miles. This is notably close to the cost estimates. It implies the Wheat Line would have been marginally profitable at best.

Note that this assumes no response on GN's part to build. We used its observed response to infer the profitability of those lines it *did not* build as a monopolist, but the Wheat Line catchment area here is computed without those GN responses having been built. Therefore it is the best-case scenario in terms of the Soo's catchment area growth. Given how marginally profitable it seems to be, any pre-emptive building by the GN in response to the Wheat Line's planned build out—even just one additional branch—may have been enough to have driven the Soo's expected profit from the line to negative territory and potentially halted entry efforts. That is, entry deterrence through product proliferation seems as if it was a viable strategy for GN to engage in once it had reason to expect the Soo was going to build the line.

3.5. **GN's Profitability of Deterrence**

Note that even if the GN *could have* deterred Soo from building the Wheat Line does not mean it would have been profit-maximizing for the GN to do so. To verify the entry-deterrence-through-product-proliferation strategy as optimal, I need to show that the GNs profit from an

effective deterrence strategy is greater than not attempting deterrence and assuring the Soo's entry. It is possible for inaction to be more profitable because the deterrence strategy involves costs—specifically, building railroad branch(es) that would not be profitable in the absence of an entry threat.

While it would be possible to more precisely quantify the GN's profit from not engaging in a deterrence strategy by making a host of assumptions, an argument that is more robust to assumptions yet still persuasive can be made with the information already at hand.

Specifically, I estimated the Wheat Line's profitability assuming the GN's unbuilt (at the time) responses to Soo entry were just marginally unprofitable. In other words, the calculation made optimistically low assumptions about line-building costs relative to operating margins. If correct, the GN's cost of building out the observed response branches would only have marginally reduced GNs profits. This would be especially so if the GN would have to build only one or two of its eventual additions/extensions to make the Wheat Line unprofitable in expectation.

That is an argument that GN's cost of deterrence would not be especially high. As to the benefit from deterrence, we know from Table 1 that GN loses 833 square miles of its 1904 catchment area to the Wheat Line. In other words, successful deterrence of the Soo would preserve 833 square miles of monopoly margins. Given the cost estimates above, this is the profit from a branch approximately 75 miles long, longer than any of the branches GN ever built and about one-third of the length of its main line in the study area. This is a notable share of its monopoly profit.

In the end, the relatively large gain in operating margin and the relatively small cost of successful deterrence would imply that this was the GN's optimal strategic response to the Soo's threated entry.

3.6. Discussion

Nevertheless, the GN did not preempt Soo's entry. It instead waited until it was clear the Soo had moved on the project to launch its response. Why did the GN respond simultaneously to the Soo's construction of the Wheat Line rather than preempt it in order to deter, particularly in light of it seeming to have been a profitable strategy? Several possibilities present themselves, but there is not dispositive evidence for any particular one of them.

One possibility is that the GN or I have miscalculated. Perhaps the GN overestimated the costs of deterrence by overestimating their building costs or the profitability of the Wheat Line. Maybe my estimates of the GN's building costs or the Wheat Line's profitability are too low.

Another possibility was that the GN's viewpoint that it was in a repeated game, where the Soo might enter in various locations in its route network. Under this scenario it may have viewed itself as developing a reputation as a particular type of strategic competitor. This raises the question, however, of why the GN would not want to develop a reputation as an incumbent who would aggressively work to deter entry, particularly if this were more profitable than waiting until entry occurred.

A still further possibility is that the GN simply did not consider or understand the deterrence scenario.

4. The Costs of Simultaneous Building

Regardless of the deeper motivations for the GN and Soo's chosen strategies and timing, one thing that may well be true is that the railroads ended up in a situation at the end of 1905 that was considerably overbuilt from their joint standpoint. Indeed it is arguable that the railroads overbuilt from the view of a social welfare as well. I explore these issues in this section.

4.1. Outcomes for the Railroad War Towns

In building its Wheat Line, the Soo founded 25 towns in 1905. The expansion GN conducted in response saw it creating 26 towns itself that year. This is a stunning amount of building in one year (really, one construction season, which is generously 6-8 months in North Dakota). I consider in this section the demographic health of these towns as a measure of the social welfare effects of the Railroad War of 1905.

Figure 5a shows the trends in decennial census population counts for three populations in the study area. The "Railroad War Towns" are the 51 towns that were built as part of the Wheat Line and GN's response. The "Railroad War Counties" are the counties that the Wheat Line crosses that do *not* also contain the GN main line. The "GN Main Line Counties" include counties in the study area that contain the GN main line. Railroad War Towns show the most direct population effect of the Soo and GN's strategic competition. Railroad War Counties offer a comparison to the Railroad War Towns that show population trends for the Wheat Line's overall area, but not directly as part of the Soo's build out of the Wheat Line and GN's response.[9] The GN Main Line Counties show broader population trends for areas in the overall region and market whose rail access was established well in advance.

[9] The Wheat Line Towns series reflects the populations of the subset of those 51 towns whose populations are reported separately by the Census Bureau. Towns that are not legally incorporated usually do not receive a reported census population; their populations are instead generally reported as part of a township (typically a 6-mile-by-6-mile area). As will be discussed below, several Wheat Line towns never incorporated and others later

As seen in the figure, among the three populations, the Railroad War Towns initially grew the fastest, rising a total of about 25 percent, from a combined population of about 6200 in 1910 to a population of 7900 in 1930. This compares to 8 percent growth in GN Main Line Counties and a slight decline in the broader Railroad War Counties.

However, the Railroad War Towns population declined in every decade after its 1930 peak. By 2020, their combined population was less than 40 percent of its 1910 level. This came both on the extensive and intensive margins; towns died, and those that lived shrank.

Comparing this to the Railroad War Counties trend, which itself falls into continuous decline, though not until 1940, reveals the Railroad War Towns' decline was part of a broader trend. The county-level population in 2020 was just under half its 1910 level. Note, however, that this decline was not as steep as that seen in the Railroad War Towns. That is, despite their "head start," the towns ultimately underperformed the broader areas in which they sat. The GN Mainline Counties series further shows that the Railroad War area considerably underperformed nearby counties served by mainline railroads that existed before the war.

Figure 5b breaks the overall Railroad War Town population trend into separate series by the founding railroad. There are a couple things to note. First, while being one fewer, Soo towns always had the larger combined population. The percentage difference changes a fair amount over time as both series fall, but the absolute difference is never more than 2200 or less than 1000 people. Second, almost all growth came from Soo Towns. GN towns' population rose slightly from 1910-1920, less than the Soo's, and never again reached as high a point.

unincorporated. The Wheat Line towns series therefore embodies both within-town population changes and shifts in the composition of incorporated towns over time. The Wheat Line counties series includes the population of the Wheat Line towns within it, as the alternative would involve confounds due to arbitrary reclassification of populations from towns' incorporations or unincorporations.

Table 3 digs further into the Soo-GN town gap. It shows difference between Soo and GN towns in two metrics of economic and social health: an indicator for the town being incorporated in 1930 (failure to incorporate, or unincorporation, is a sign of a struggling town), and the inverse hyperbolic sine (IHS) of the town's 2020 population.[10] These outcome variables are regressed on an indicator for a Soo Line town, so the coefficient reflects the average difference in outcomes between Soo and GN towns. The three specifications for each outcome differ in their control sets. One specification includes no controls. Another has county fixed effects to control for local variations in soil conditions or relevant differences in local governments. A third includes fixed effects for one-degree bands of latitude and longitude to capture any systematic differences in terrain or soil conditions.

Table 3. Relative Outcomes of Soo and GN Towns

	Incorp. in 1930	Incorp. in 1930	Incorp. in 1930	IHS Pop 2020	IHS Pop 2020	IHS Pop 2020
Soo	0.417	0.326	0.339	1.80	1.25	1.23
	(0.125)	(0.157)	(0.146)	(0.62)	(0.73)	(0.73)
County FE	No	Yes	No	No	Yes	No
Lat, Long FE (1°)	No	No	Yes	No	No	Yes

The results in the table reveal the Soo towns fared systematically better in both metrics. They were 41.7 percentage points more likely to be incorporated in 1930 (only 42.3 percent of the 26 GN towns were incorporated, as opposed to 84 percent of Soo towns). The difference remains significant after adding controls. Soo town populations in 2020 were substantially higher

[10] As explained above, the latter value is zero for unincorporated towns. Hence the use of the IHS functional form rather than the logarithm.

as well, though the large point estimate of the difference (about a 3.5-fold population ratio) becomes insignificant with controls.[11]

While the Soo's towns outperformed those of the GN, the Railroad War towns collectively struggled. If we divide their respective total 2020 populations by the number of towns originally founded (25 Soo and 26 GN), the averages per founded town are approximately 49 for all towns, 78 for Soo towns, and 21 for GN towns. Towns of such size are obviously not regional or even local centers of commerce. Indeed, the population that remains might be there in substantial part because of hysteresis and its effect on the cost of housing (Notowidigdo 2020).

4.2. Outcomes for the Railroad War Railroad Lines

The fact that the towns founded during the Railroad War struggled economically within just a couple decades of founding and continue to do so today suggests that the railroads themselves that were built in the war—both the Soo's Wheat Line and the GN's several responses to it—faced similar viability issues.

This is correct. Figure 6 shows the study area's railroads as currently configured. The dashed lines show lines abandoned since the apex following the Railroad War. (No additional railroads were built in the study area after this time.) The main lines that formed the border of the study area—the GN's as well as both of the Soo—continue to operate today. The GN main line is operated by the present-day BNSF, which was formed from the merger of several railroads

[11] In two cases, I can make the Soo-GN town comparison while controlling for location very precisely. This is because in those instances the railroads placed their respective towns only a few hundred yards apart, at points were the lines crossed. Olmstead (GN) and Egeland (Soo) were one co-located pair and McCumber (GN) and Rolette (Soo) another. In both cases, reflecting the broader patterns seen here, the Soo line town survived while the GN town did not. Indeed, Rolette was the most populous of the original 51 Railroad War towns in 2020.

including the GN.[12] The BNSF also still operates the two GN branches that extended into Canada, one each toward the west and east ends of the study area. The Soo main lines are operated by the Canadian Pacific, the Soo's former partner. Through a series of financial purchases and reorganizations over the past several decades, the CP turned the Soo into a wholly owned subsidiary, eventually dropping the Soo branding. Thus the activity that first brought the railroads to the area over 120 years ago remains robust enough today to support continued operation by Class I carriers, the category containing the largest railroads in North America.

The story is different along the terminal branch lines, however. Most of this mileage has been abandoned. The majority of the lone NP branch is abandoned, with short remaining portions operated by either the BNSF or the short line Northern Plains Railroad. The BNSF operates some short distances along former GN branches, as does the short line Dakota Northern Railroad, but most of the mileage was abandoned starting decades ago. The Wheat Line itself has been split into two segments. A 65-mile length in the middle has been abandoned, while the remaining west and east segments are operated by the Northern Plains Railroad (the east segment includes a portion of the Armourdale extension). Given the contrast between the abandonments in the Railroad War area and the still-viable nearby main lines, it is hard not to conclude that the simultaneous building "race" of the Railroad War ended up with the market area being far more saturated than underlying fundamentals could sustain.

5. **Conclusion**

[12] In 1970 the GN merged with the NP; the Spokane, Portland and Seattle Railway; and the Chicago, Burlington and Quincy Railroad to become the Burlington Northern. The Burlington Northern in turn merged with the Atchison, Topeka and Sante Fe in 1996 to become BNSF.

While objects of extensive conceptual analysis and discussion, detailed empirical investigations of strategic behavior involving threatened and actual entry are somewhat rare due to difficulties in obtaining the necessary data. In this paper I have taken advantage of a historical episode in the U.S. railroad industry to study a particular form of strategic entry responses, the product proliferation mechanism posited in Schmalensee (1978). I have been able to analyze not just the profitability of the strategic decisions of the parties themselves, but also explore some of the broader social welfare effects of this interaction.

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Figure 1a: Great Northern Railway Network Circa 1912



Figure 1b: Study Area Wide View Showing Relevant Great Northern (Black) and Soo Line Railways (Red)

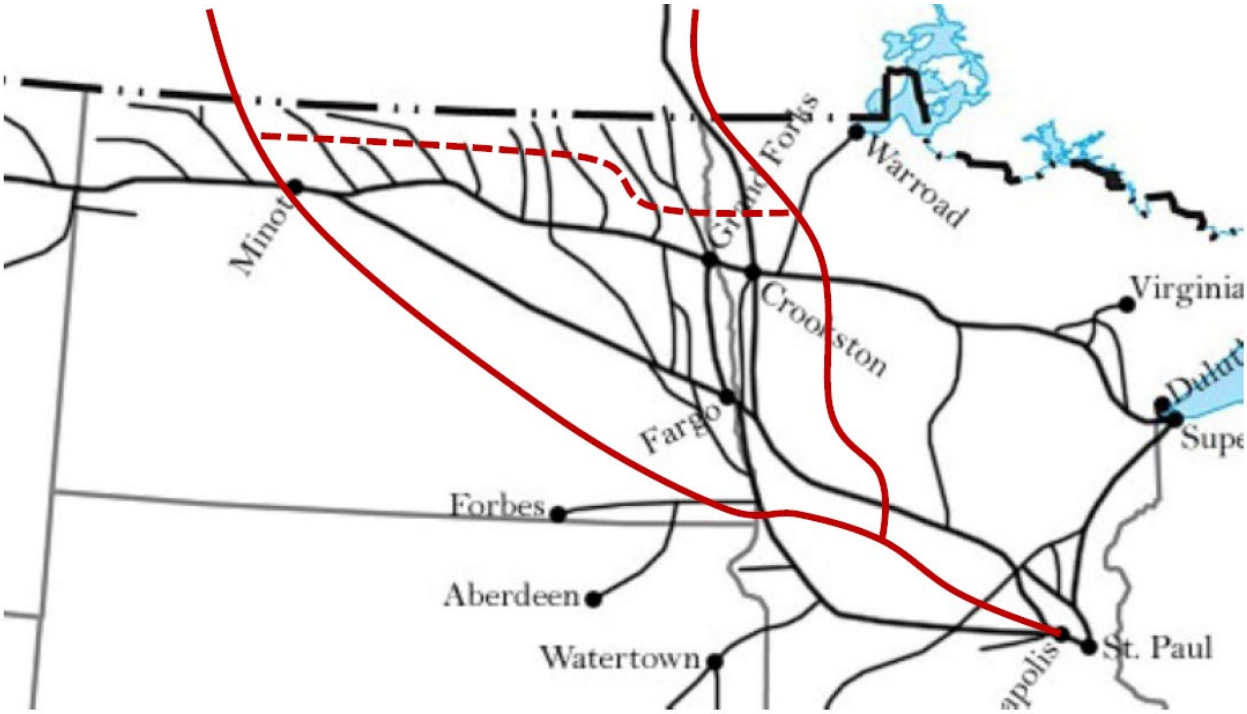


Figure 2: Situation in 1904 in Study Area

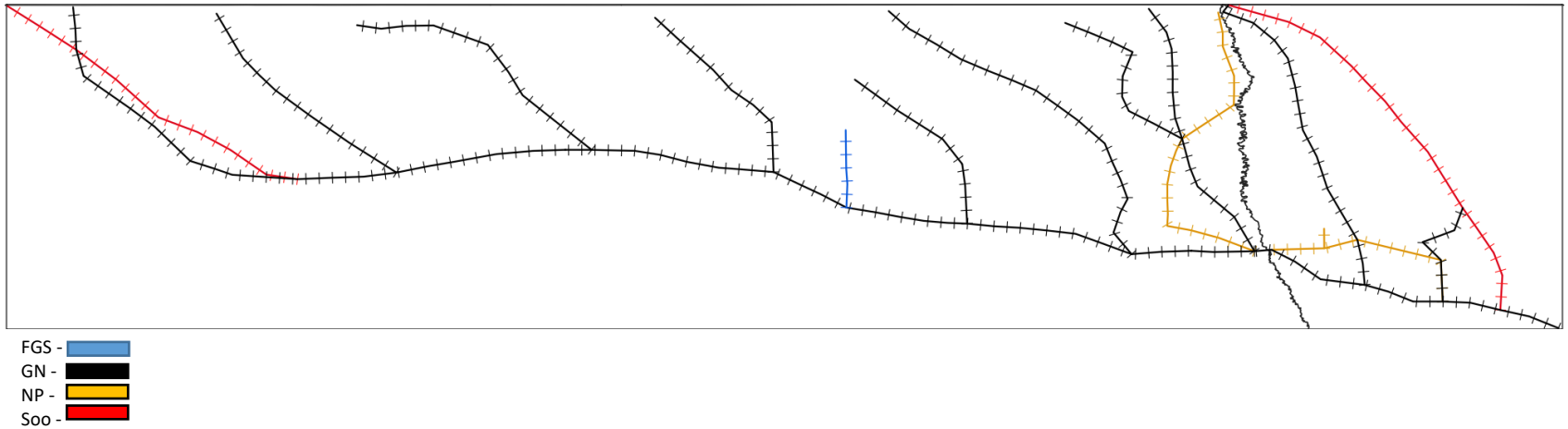


Figure 2b: Wheat Line Added

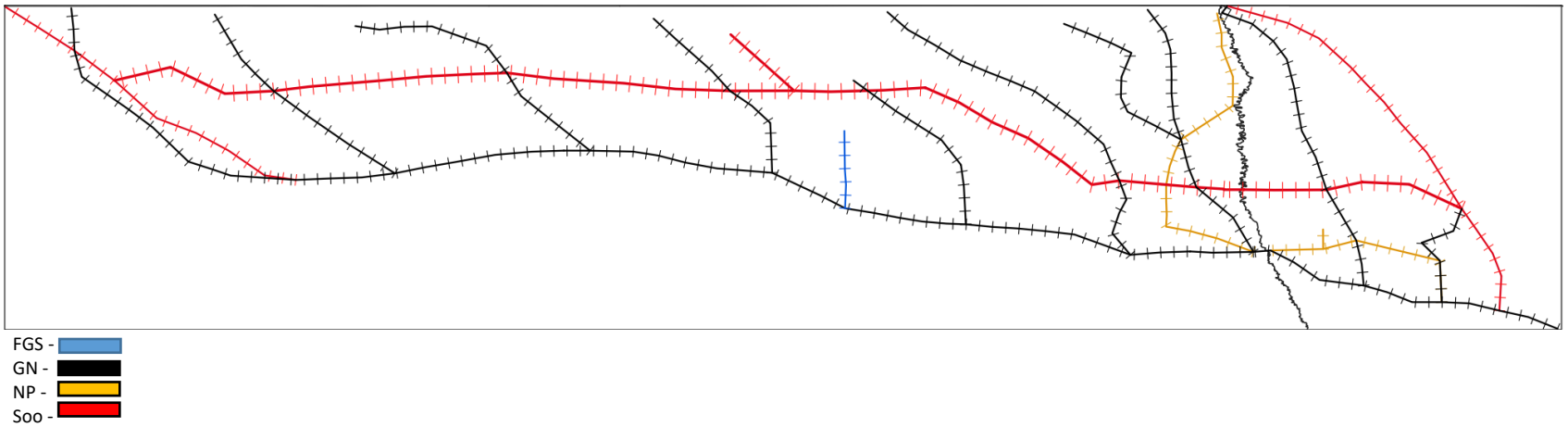


Figure 3a: Voronoi Diagram for 1904



Figure 3b: Catchment Areas for 1904

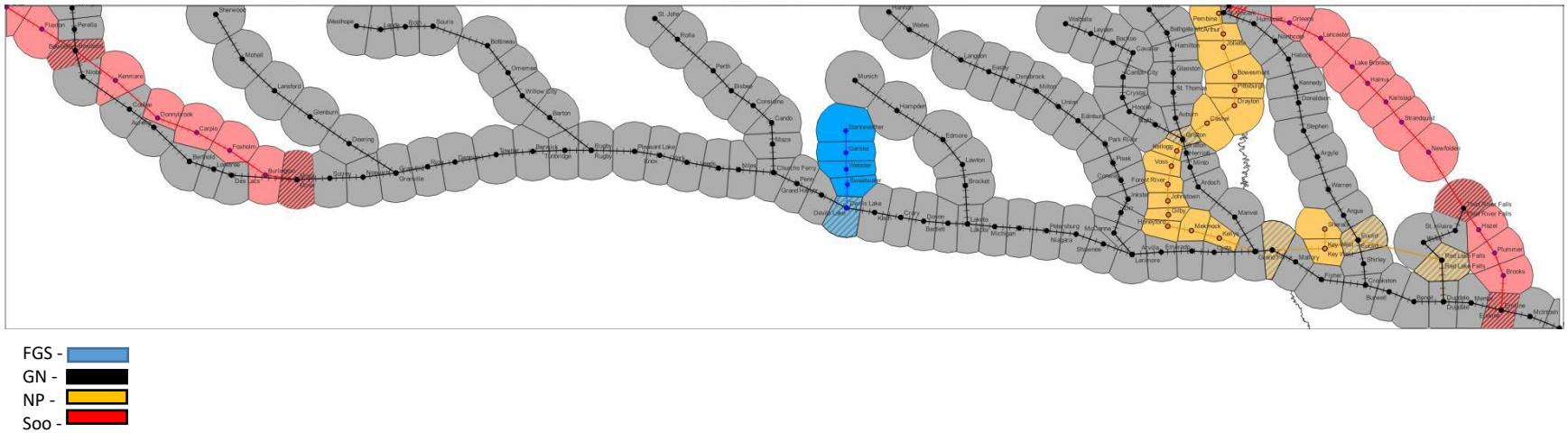
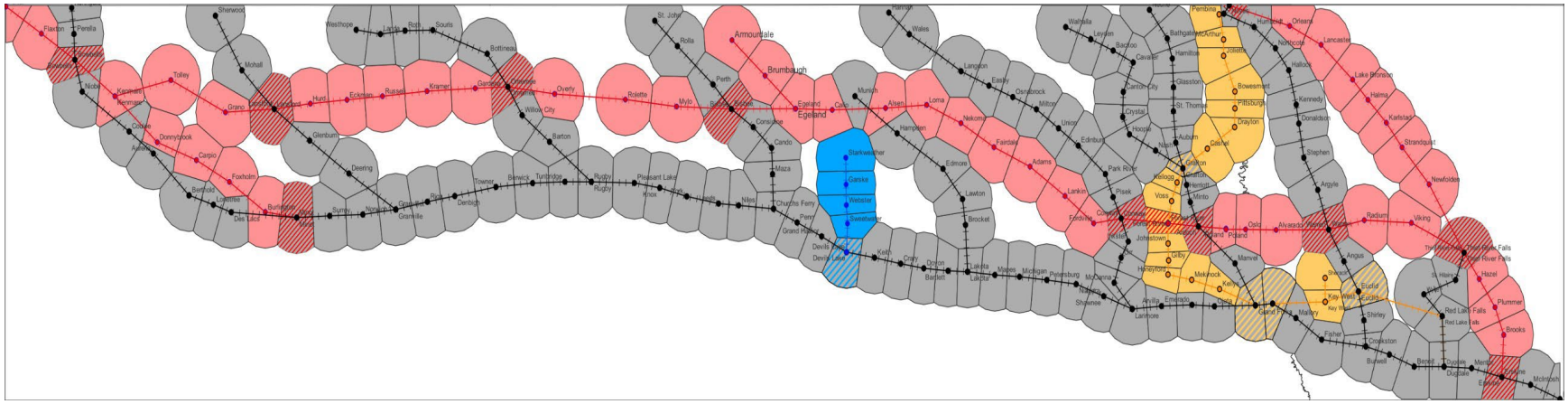
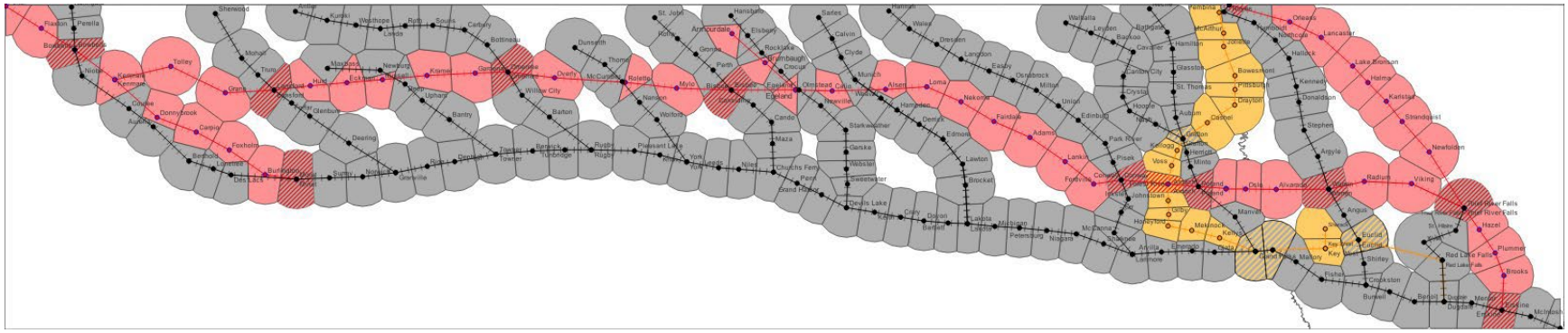


Figure 4a: Catchment Areas with Wheat Line Added



FGS -
GN -
NP -
Soo -

Figure 4b: Catchment Areas with GN's Response to the Wheat Line Added



FGS -
GN -
NP -
Soo -

Figure 5a: Population Indexes: Railroad War Towns, Railroad War Counties, and GN Mainline Counties

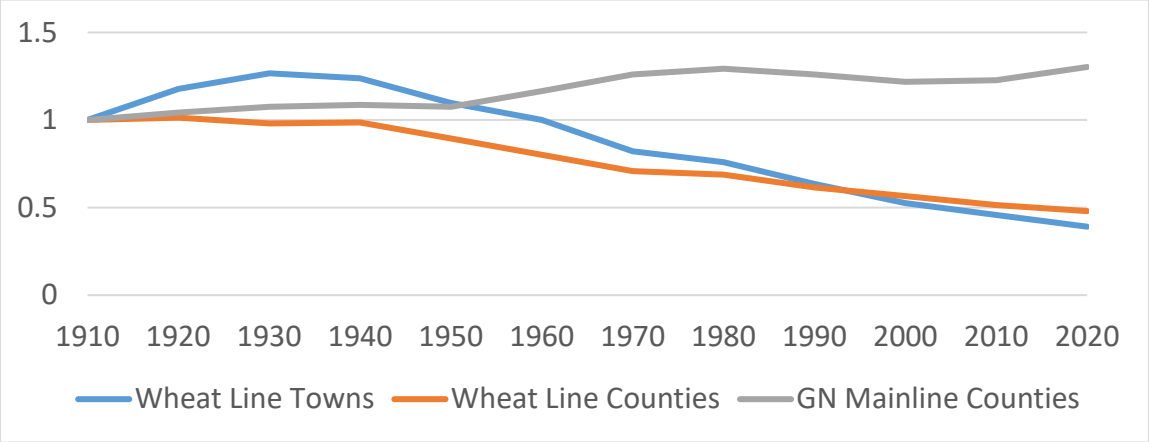


Figure 5b: Railroad War Town Total Populations by Founding Railroad

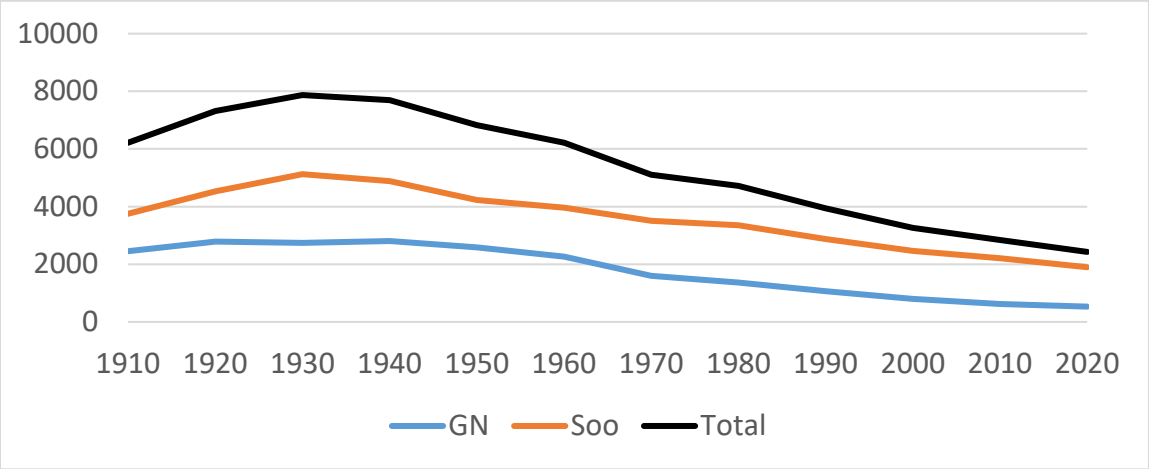


Figure 6: Railroads of the Study Area Today

