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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 arguably 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.

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

[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.

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 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, to my knowledge it has not been previously explored by economists nor 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, 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 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 diagonal 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. The GN had 13

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[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).

northern branches in the 310-mile span of North Dakota, while only having 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 my 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 met 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 (via another line not shown) 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 was 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 rich set of historical documents involving this market and the companies competing within it. These include corporate financials, correspondence, and elements of strategic planning. This allows me to understand many 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

The GN was the dominant incumbent in the study area and much of northern Minnesota, North Dakota, Montana, Idaho, and central Washington more generally. It offered service both along its main line and on multiple branch lines extending 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 railroad industry leader at the time. As I detail below, I

[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.

leverage 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 business. 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 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 connecting Thief River Falls, MN on their eastern line and 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 was never 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 it. (The NP was built out considerably more 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, 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—enough in this case to actually build their own railroad—is a convenient fact that I use below to infer line-building costs. 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 its owners' intents, the FGS was tightly capitalized and unlikely to be able to expand aggressively even if it wanted to. As we will see, however, once the Soo planned to build the Wheat Line, the GN did not view the FGS completely as a given entity the way it did the NP.

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, this means 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 estimate the Soo's expected profitability from building the Wheat Line.

3.1. Computing Railroads' Catchment Areas

Railroad product differentiation in this market was 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 usually 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 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 that necessary for depots, warehouses, and maintenance facilities. Instead, they worked with private developers who would plan the town and sell residential and commercial lots to homeowners and businesses.

One business present in every town was a grain elevator; often, there were multiple. Elevators were owned and operated by specialized firms. They bought farmers' harvested grain 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 (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' latitudes 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 are not covered separately by the Census) or are now ghost towns, I used satellite pictures from Google Maps to identify the town's most likely location.[5] The area within the plane closest to each town is contained in the town's Voronoi polygon.

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

[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 from 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 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.

the firms at the time; when the Soo estimated the Wheat Line's catchment area in preparation for building it, the Soo assumed it would evenly split commercial traffic in contested towns.

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 implies 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. Any towns outside the study area are ignored when constructing catchment areas. However, this arbitrary element has no practical effect on the analyses here. All the relevant catchment area computations involve area *changes* as railroads are (notionally) built. Because 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]

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. Assuming the volume of commercial traffic in a town is proportional to its catchment area, no matter how large that area or how far away points within it are from the town, effectively assumes economic activity is uniformly distributed throughout the catchment area, and every farmer within is equally likely to haul their grain to the town regardless of the distance. This is inconsistent with reality. Traveling and shipping to and from a town is costly, even if it happens to be the nearest one. Areas situated within the catchment area further from the town are less likely to see cash crop farming, or to be occupied by farmers at all. To account for this, I do not use the simple area of a town's Voronoi polygon to calculate its catchment area. Instead, I calculate an effective catchment area that up-weights locations within the polygon closer to the town.

[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 are major besides the Red River, which I treat by not allowing Voronoi polygons to cross it. 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 by 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 border for sale, cross-border grain transport (in either direction) was not common in practice.

I apply different weighting schemes to check the sensitivity of the results to the assumed weights. The first is very simple and motivated by the railroads' own reckoning with farmers' practical limits of cartage. When the Soo estimated its catchment area from the proposed Wheat Line, it assumed the area would extend 9 miles from the line, albeit with equal weight applied anywhere within that radius. It assumed the same for the GN's catchment area of the GN branch lines that it crossed, consistent with its aforementioned presumption of symmetry of it and its competitor. Based on this, I conduct a set of analyses where I calculate effective catchment areas for towns as the intersection of their Voronoi polygon and a circle centered on the town with a 9-mile radius. Figure 3b shows these adjusted catchment areas.

The advantages of this approach are its ties to historical views of the market's firms and the ease of calculating the intersecting areas within GIS software. The major drawback is that it assumes a very stark function for travel/shipping costs as a function of distance. Travel/shipping is effectively costless up to 9 miles, whereupon it immediately becomes infinite.

To move away from such a discontinuous weighting function, I also calculate effective catchment areas using weighting functions that decline in distance from the town. I use various of inverse logistic functions of the form $w(d) = 1/\left[1 + e^{k(d-d_0)}\right]$, where d is the distance from a location to the polygon's focal town. I plot the four parameterizations I use in Figure A1 in the appendix (for comparison, the stark weighting function above has a value of 1 up to 9 miles and 0 beyond that).

All these functions give maximum weight to the location of the town itself. This maximum weight is normalized to 1, which can be thought of intuitively as implying a hypothetical farmer co-located with the town will conduct their commerce in that town with probability 1. The functions differ in their parameterizations of k and d_0. The value k influences the steepness of the weights' decline in distance, and d_0 determines the distance at which the weight equals 0.5. I base my parameterizations on various interpretations of the railroads' 9-mile assumption. I choose k and d_0 to imply the weight at a 9-mile distance from the focal town is either 0.1, 0.25, or 0.5 (interpretable as implying the probability that cash-crop farming at that distance both exists and is tied to the polygon's focal town is respectively 10, 25, and 50%). Three of the four weighting functions have a common k and manipulate d_0 to obtain the desired weights at 9 miles. The remaining function has a 0.5 weight at 9 miles but changes k to yield an earlier but less steep decline in weights (thereby also yielding higher weights at longer distances). Regardless, all four weighting functions have what I view as a historically realistic slow initial decline in distance. For example, each has a weight greater than 0.96 at a distance of 4 miles from the town. As distance grows, the weights fall in distance with increasing speed. At 12 miles, all have weights below 0.04 except the less-steep parameterization, which has a weight just under 0.13 at that distance.

With the smooth weighting functions, I must numerically integrate to compute the effective catchment area. I do so by creating a grid of points within the Voronoi polygon. Each point represents a small area of the polygon (either a square one half mile on a side or, for points at the perimeter, the intersection of that square and the edge(s) of the Voronoi polygon). This point/area is given a weight implied by the weighting function. These are then summed throughout the polygon to obtain the effective catchment area. The reported results below use a grid spaced at 0.5 miles (thereby implying about 1018 points within a 9-mile-radius circle). The computed effective catchment areas are not sensitive to using finer grids.

3.2. Computing the Wheat Line's Catchment Area

Figure 4a shows the catchment area under the assumption of the 9-mile limit of the Wheat Line as proposed and built. Figure 4b shows the unlimited Voronoi polygons over which the reverse logit weighting functions are integrated. Both figures keep the GN's lines as they were in 1904, if GN never responded to the Soo's entry. Table 1 shows the computed changes in the four railroads' effective catchment areas in this scenario for the various weighting functions.

Table 1. Catchment Area Changes (mi^2) If Soo Builds Wheat Line without GN Response

	Weighting Function				
Railroad	Uniform to 9-mile hard limit	0.1 at 9 miles	0.25 at 9 miles	0.5 at 9 miles	0.5 at 9 miles, slower weight decline
Soo	3239	2794	3107	3343	3195
GN	-827	-799	-1082	-1396	-1433
NP	-12	-9	-15	-21	-19
FGS	-21	-23	-25	-28	-30

Depending on the weighting function, my calculations imply building the Wheat Line would increase the Soo's effective catchment area by somewhere between 2800 and 3300 square miles. These values are notably consistent given the span of weighting functions; their coefficient of variation is 0.067. The GN's resulting loss in its effective catchment area is more sensitive to the weighting function, ranging from about 800 to 1400 square miles. Its lost effective catchment area is largest when the weighting function is relatively larger for more distant locations. This implies much of the Wheat Line is relatively distant from GN branches, so the catchment area it pulls from the GN depends on what occurs in the further-flung regions of towns' 1904 Voronoi polygons. The NP's and FGS's lost catchment areas are much smaller.

Historical documents indicate that before embarking on the project, the Soo estimated the Wheat Line's catchment area by roughing out a route on paper maps. 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 a projected catchment area of 1.99 million acres. Given 640 acres in a square mile, my calculation here using the "uniform to a 9-mile hard limit" weighting function (effectively what the Soo used in its own estimate) implies a Wheat Line catchment area of 2.07 million acres. This is almost identical to the Soo's number, a testament to the company's care in planning the route.

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. I leverage the GN's effective monopoly in the area through 1904 to do so. Specifically, 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 estimate profitability using the fact that there were lines it didn't build before the Wheat Line, but did build after.

Before explaining the estimation process, it is important to note that the historical record is consistent with the GN believing it had built out the profit-maximizing monopoly route network before 1905. First, 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. Second and 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, explaining the unprofitability of such an extension (and sometimes complaining about the strictures of state 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.

Assuming a monopoly profit-maximizing network means that any additional building the GN could have done would have been unprofitable in expectation. I can use these hypothetical projects to learn about the parameters of the profit function.

Of course, there are an infinite number of projects 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. It built 250 miles of railroad: two entirely new branches, the extension of two others, and the purchase and tripling the length of the FGS. If founded dozens of towns on these new and extended lines, including seven that it established on its 1904 existing lines. Figure 5 shows these new and extended lines and towns added to existing lines in bold. Figure 6a plots their corresponding catchment areas to the study area map under the 9-mile limit weighting function, and Figure 6b shows the Voronoi polygons for the other functions.

I use these unbuilt-until-Soo-entry lines to learn about the expected profitability of building railroad branches. My calculation works as follows. Separately and for each of these unbuilt-until-Soo-enters lines, 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 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. Through this, I 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).

[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 under GN's monopoly. I calculate the effective catchment areas for each branch assuming only that branch was built, so as to identify the cost of building that line in isolation (though of course this single-line effect includes any cannibalization of existing GN catchment area). Table 1A in the appendix shows the calculated changes in effective catchment areas that result from building or extending each branch line.

Specifically, I assume the profit from building a branch line *l* of length l_l that gains effective 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 catchment area. I posit this margin is constant everywhere along the line. Parameter c_1 captures the per-unit-length building cost, and f_l is the fixed cost of building the branch.[9]

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., $\pi_l = 0$. (This optimistic view of the just-barely-unprofitable hypothetical project implies my cost estimates are likely to be lower bounds.) Then I 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*. That is unnecessary, however. Because it is a constant, I can divide through (2) by *PDVmargin* to obtain my regression specification:

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

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.

Table 2 shows the estimates of the cost parameters from specification (3), separately for each of the five weighting functions described above. It shows estimates for two samples. Panel A treats the FGS acquisition and its extension as a single project. Panel B considers them separate projects, each with its own fixed cost.

Despite the small sample size and different weighting functions, the point estimates are remarkably similar. In every case, the estimated fixed cost is not statistically distinguishable

[9] 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. Two relevant factors were at work in the study area. One was the Turtle Mountains, a forested area of rolling hills extending roughly 40 miles east to west, straddling the central North Dakota-Manitoba border. The geologic exception to the flat plains around them, these "mountains" were not friendly to either farming or building railroads. Any branch that approached them stopped before entering. The second and more broadly applicable factor was 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).

from zero, suggesting marginal costs drive rail-building efforts. The estimated per-mile costs are remarkably precise given the sample sizes. In the FGS-as-one-project sample, the estimated per-mile cost averages around 11.3 square miles of operating margin present value. The FGS-as-two sample has an average estimated cost of 10.0 square miles of margin per mile built.[10]

Table 2. Estimated Railroad Building Cost Parameters

	Weighting Function				
	Uniform to 9-mile hard limit	0.1 at 9 miles	0.25 at 9 miles	0.5 at 9 miles	0.5 at 9 miles, slower decline
A. Treating FGS purchase and extension as one project (n = 5)					
f (fixed cost)	-21.4	-15.9	-17.9	-12.7	-11.5
	(29.0)	(9.7)	(17.9)	(28.7)	(36.9)
c_1 (per-mile cost)	10.9	11.7	10.9	11.4	11.5
	(0.7)	(0.3)	(0.4)	(0.8)	(1.0)
Estimated Wheat Line cost (mi^2 of margin)	3293	3548	3300	3563	3496
B. Treating FGS purchase and extension as separate projects (n = 6)					
f (fixed cost)	12.2	24.6	26.4	31.6	39.9
	(40.8)	(57.1)	(70.8)	(85.0)	(86.5)
c_1 (per-mile cost)	10.9	9.6	10.2	10.2	9.0
	(1.3)	(1.6)	(2.2)	(2.8)	(2.5)
Estimated Wheat Line cost (mi^2 of margin)	3360	2987	3174	3184	2834

The cost specification above does not include a separate cost to the railroad of founding towns along the line; instead such costs are assumed to be rolled into the per-mile tab. This may be reasonable given the high correlation between the length of a branch or extension and the number towns built along it. And as a practical statistical matter, the collinearity plus the very small sample prevents identifying separate per-mile and per-town costs. Nevertheless, if separate town-founding costs are important and somehow missed in the cost specification above, GN's actions offer a way to measure town-founding costs. Besides extending and building new lines,

[10] It is reassuring that these are less than 18 square miles of margin, as under the Soo's 9-mile assumed catchment area limit, extending a branch one mile would increase its catchment area by 18 square miles at most. Any cost estimate greater than that would imply the Soo's estimated variable profit of building *anything* would be negative.

GN also founded seven new towns on existing lines. Not surprisingly, these were located where there were unusual gaps between existing towns on a line. The new towns increased the effective catchment of existing lines, albeit at some cannibalization cost. I compute the change in effective catchment area from these new towns. By the logic above, if building these towns in absence of the Wheat Line threat would have been (just) unprofitable, the net increase in GN's effective catchment area they create offers a lower bound on the cost of founding the towns. I report the seven-town total computed changes in effective catchment areas by weighting function in Table A1. Across all specifications the average per-town catchment area, and therefore implied founding cost, is 16.3 square miles. While I do not include this separate town-funding cost into the Wheat Line profitability analysis below—I rely on its concomitance with the per-mile build cost—to the extent my procedure understates true railroad building costs by leaving out town-founding costs, it is easy to add in this 16.3 square miles per town.

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.

The Wheat Line as proposed had 306 miles of track. To obtain the estimated cost of building it, I multiply this by the estimated per-mile cost c_1. For fixed cost f, I assume the Soo pays it twice. The Wheat Line connects two main lines, and as built the Soo sent separate crews to each end and had them meet in the middle. I do not assume a third fixed cost for the Armourdale extension, though it would be straightforward to add that to the estimates below. In any case, the treatment of fixed cost matters little, as the estimates are not just statistically insignificant but economically small as well.

The bottom of the panels in Table 2 report the total estimated cost of the Wheat Line using the cost parameters from each sample and weighting function. Given the similarities seen in the parameters, it is not surprising that the estimated total Wheat Line costs are also similar (the coefficient of variation across all 10 estimates is less than 7 percent). The average estimate implies building the Wheat Line involved a total cost of 3264 square miles' of present value of the operating margin.

The critical comparison is in placing these estimates alongside my estimates above of the Soo's gain in effective catchment area. There, the average computed gain was 3136 square miles. This is actually slightly *below* the estimated cost. Taken as a point estimate, it would imply the Wheat Line would have been marginally unprofitable. The additional catchment area brought by the line would not yield enough future profit to pay for the cost of building it. If I pairwise compare cost and catchment area estimates across samples and weighting functions, eight of the ten have higher estimated costs. Only in two cases—the sample that treats the FGS acquisition and extension as two projects and where the weighting functions that assume a 50% probability of town-centered commerce at 9 miles—are the Soo's estimated costs of building the Wheat Line less than the increase in effective catchment area it obtained from it. In those cases, the effective catchment areas are about 5 percent (the weighting function with a faster-declining weight) and 13 percent (the slower-declining weight) larger than costs.[11]

Note that this analysis assumes no response to the Wheat Line on GN's part. The effective catchment areas computed above take the GN's 1904 configuration as given. It is therefore the best-case scenario in terms of the Soo's catchment area growth.

Given that the Wheat Line seems to be only marginally profitable even under the most optimistic scenarios, any pre-emptive building by the GN in response to it—even just one additional branch—appears likely to have been enough to have driven the Soo's expected profit into negative territory. If this occurred and the Soo recognized the implications as such, it may have halted entry efforts. In other words, 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**

There is one more step in the strategic analysis. Even if the GN *could have* deterred Soo from building the Wheat Line, it does not guarantee it would have been profit-maximizing for the GN to do so. To verify the entry-deterrence-through-product-proliferation strategy as

[11] Remember, there are reasons why the costs here may be lower bounds. First, I assumed the GN's lines were just marginally unprofitable in absence of strategic considerations. Second, I have not added in any additional town-funding costs that the per-mile cost might miss. Doing so would multiply the town-founding estimated cost of 16.3 square miles of operating profits by the 25 towns the Soo founded on the line, adding another 408 square miles of operating profit to the cost estimate.

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 additional assumptions, an argument that strikes me as robust to assumptions yet still persuasive can be made with the information already at hand.

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 as a monopolist would have reduced GNs profits, but only marginally so. This would be doubly true if the GN only had to build 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 its benefit from deterrence, I know from Table 1 that GN loses somewhere between 800 and 1400 square miles of its 1904 effective catchment area to the Wheat Line. In other words, successful deterrence of the Soo would preserve about 1000 square miles of (inframarginal) monopoly profit. Given the cost estimates above, this is the profit from a line up to about 100 miles long. This is longer than any of the branches GN ever built and almost half of the length of its main line in the study area. This seems a notable share of its monopoly profit.

In the end, the rather large amount of operating margin preserved 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

Despite the implications of the analysis above, the GN did *not* preempt Soo's entry. It instead waited to launch its response until it was clear the Soo had moved forward with the project. 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 the calculations above? Several possibilities present themselves, but there is not dispositive evidence for any particular one of them.

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

Another possibility is that the GN's viewpoint was that it was engaged 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 in a way that mattered beyond the interaction in this study area. 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. The most obvious dynamic extension to the stage game here would seem to only deepen the GN's incentive to preempt.

A still further possibility is that the GN simply did not consider or understand the deterrence scenario, and its choice to wait until the Soo started building the Wheat line was less of a deliberated delay than the only scenario the GN could have imagined.

4. **The Costs of Simultaneous Building**

Regardless of the deeper motivations for the GN and Soo's chosen strategies and timing, the fact that they did aggressively build simultaneously opens the possibility that the situation at the end of 1905 was one of considerable overexpansion 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 the demographic health of these towns as a measure of the social welfare effects of the Railroad War of 1905.

Figure 7a shows the trends in decennial census population counts for three populations in the study area. "Railroad War Towns" are the 51 towns built in 1905 as part of the Wheat Line and GN's response. "Railroad War Counties" are the counties that the Wheat Line crosses that do *not* also contain the GN main line. "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's entry and GN's simultaneous response. Railroad War Counties offer a comparison to the Railroad War Towns that reveal 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.[12] 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.

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, the towns' 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. County populations in 2020 were just under half the 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 Main Line Counties series further shows that the Railroad War area considerably underperformed nearby counties served by mainline railroads existing before the war.

Figure 7b 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

[12] 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 do not usually 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 discussed below, several Wheat Line towns never incorporated and others later 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 lead to confounds due to towns' incorporations or (more often) unincorporations.

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.

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 are signs of a struggling town), and the inverse hyperbolic sine (IHS) of the town's 2020 population.[13] 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 account 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 percent of the 26 GN towns were incorporated, as opposed to 84 percent of Soo towns. This difference remains significant after adding controls. Soo town populations in 2020 were substantially higher as well, though the large point estimate of the difference (about a 3.5-fold population ratio) becomes insignificant with controls.[14]

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

[14] In two cases, I can make the Soo-GN town comparison while controlling for location very precisely. 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

While the Soo's towns outperformed those of the GN, the Railroad War towns collectively struggled. If I 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 8 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 including the GN.[15] 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 small remaining portions operated by either the BNSF or the short line Northern Plains Railroad. The BNSF

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.

[15] 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.

operates some short distances along former GN branches, as does the short line Dakota Northern Railroad, but most of the mileage began to be abandoned 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**

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)

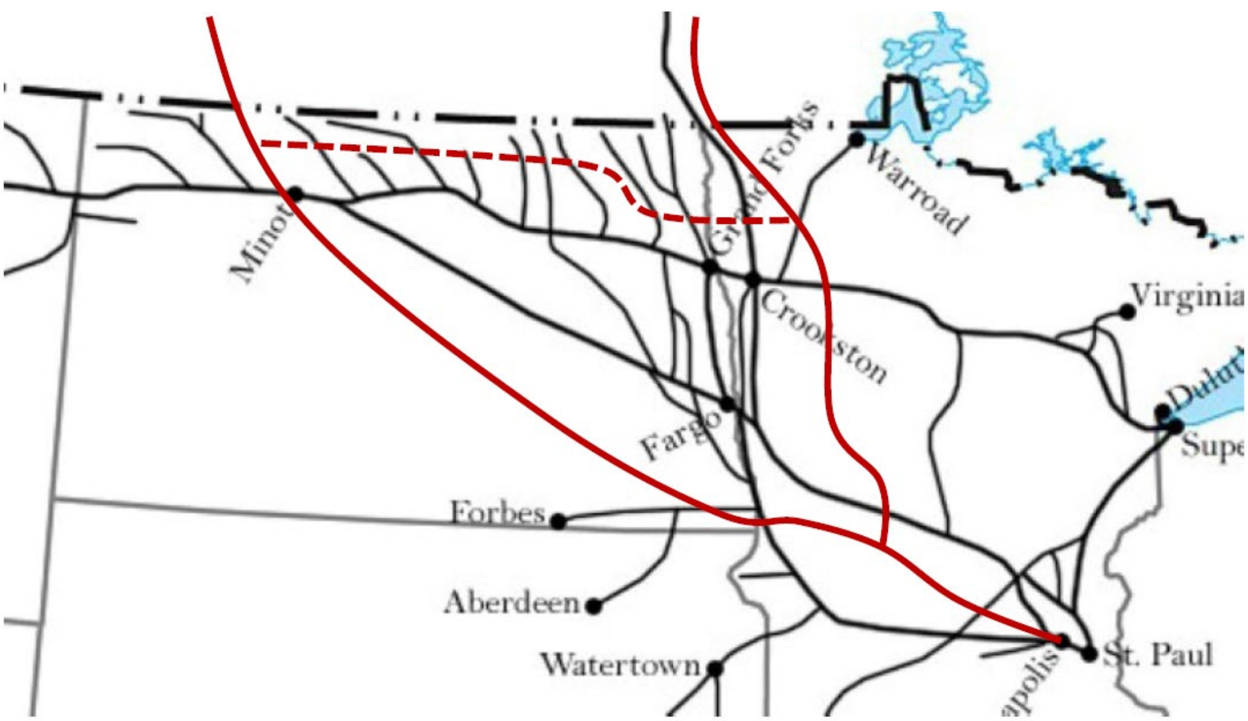


Figure 2: Situation in 1904 in Study Area

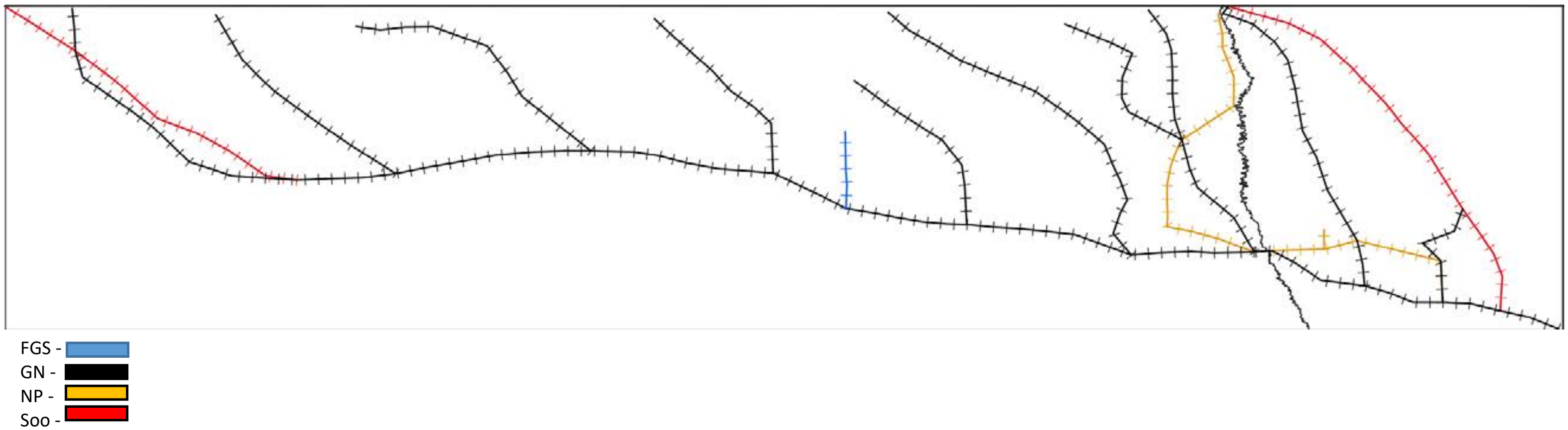


Figure 2b: Wheat Line Added

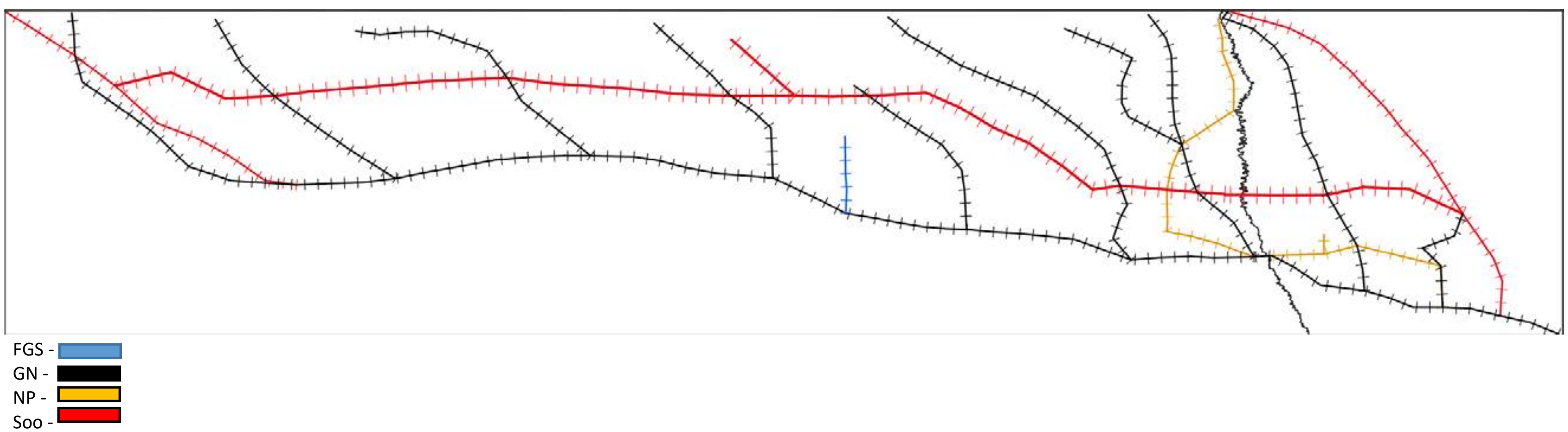
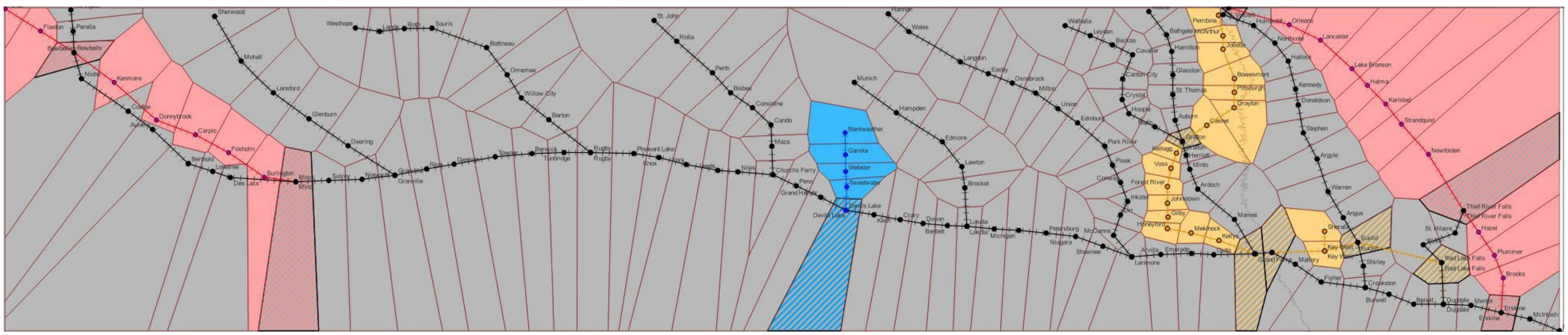
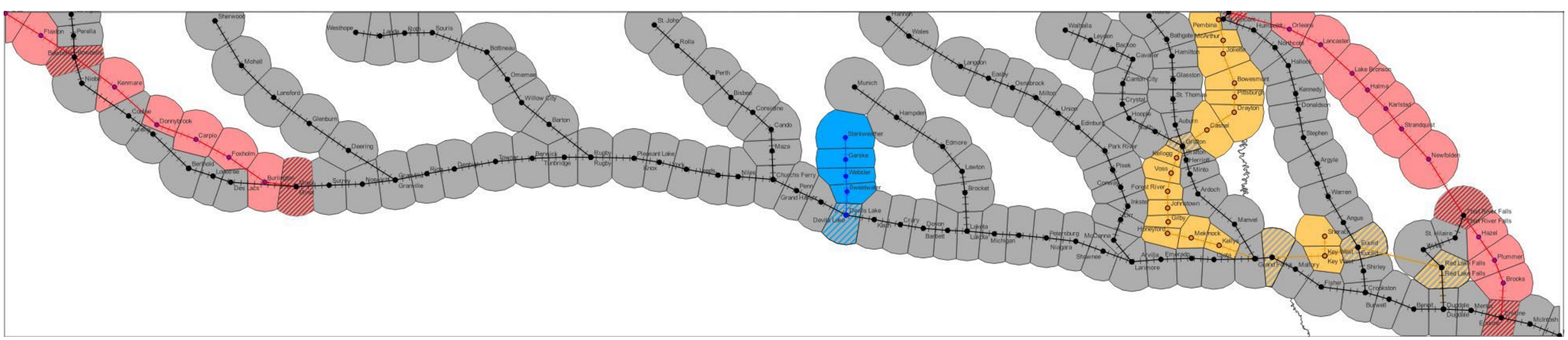


Figure 3a: Voronoi Diagram for 1904



FGS -
GN -
NP -
Soo -

Figure 3b: Catchment Areas for 1904, 9-mile Limit Imposed



FGS -
GN -
NP -
Soo -

Figure 4a: Catchment Areas with Wheat Line Added, 9-mile Limit

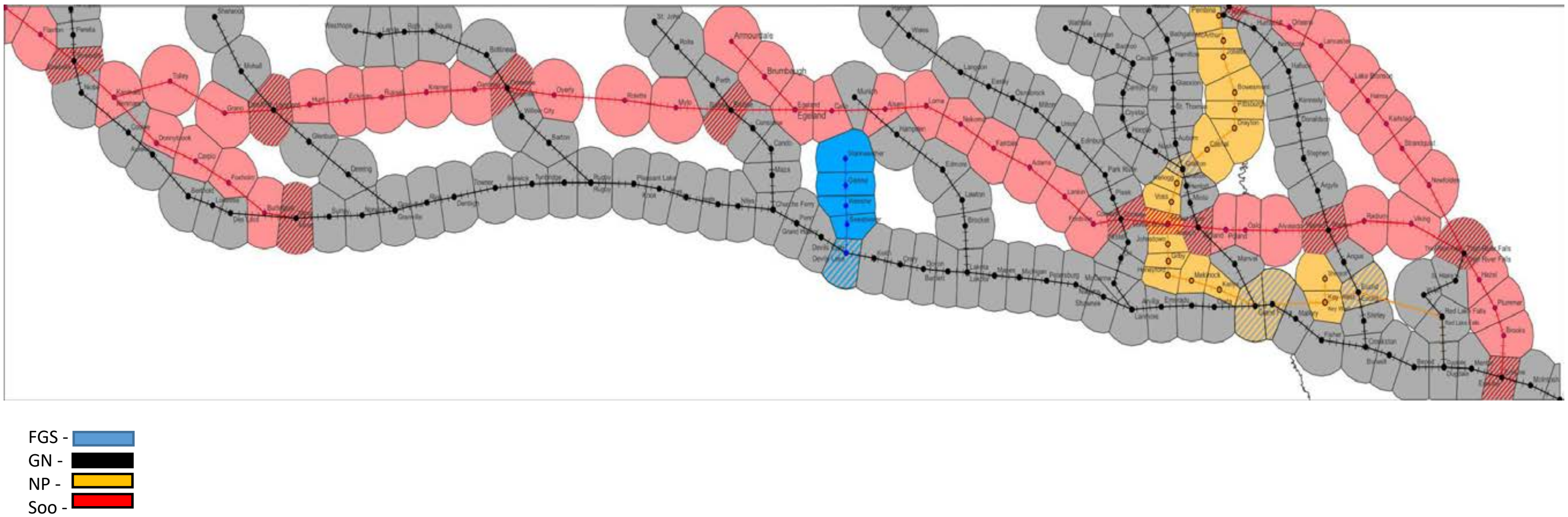


Figure 4b: Catchment Areas with Wheat Line Added, Voronoi Polygons

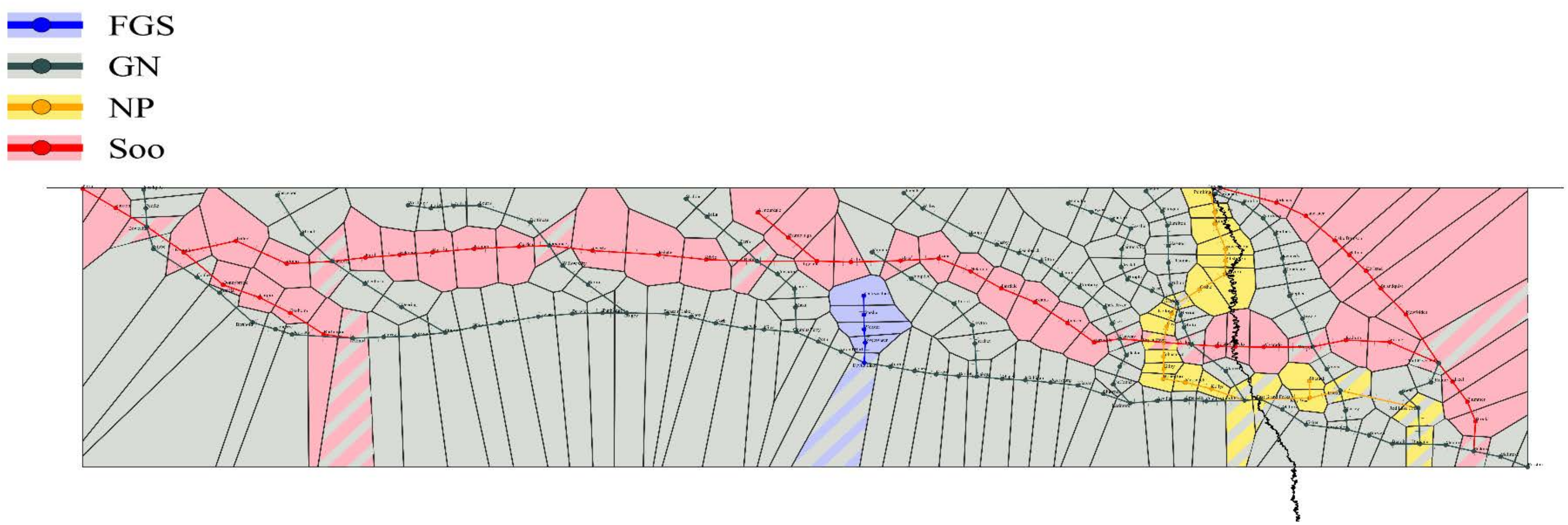


Figure 5: GN's Responses to the Wheat Line

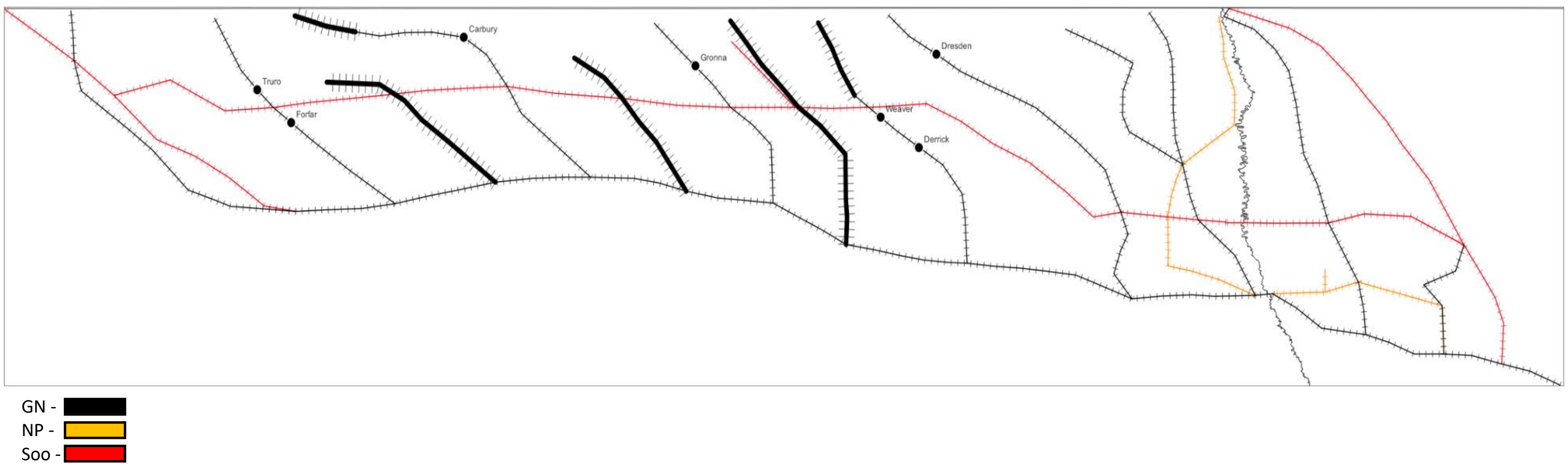


Figure 6a: Catchment Areas with GN's Response to the Wheat Line Added, 9-mile Limit

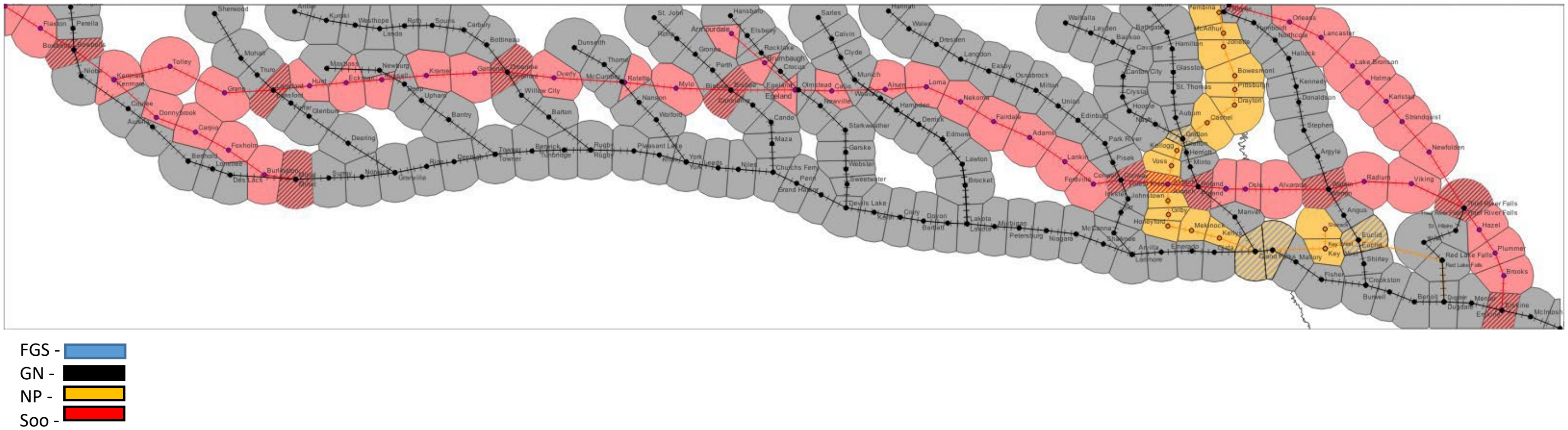


Figure 6a: Catchment Areas with GN's Response to the Wheat Line Added, Voronoi Polygons

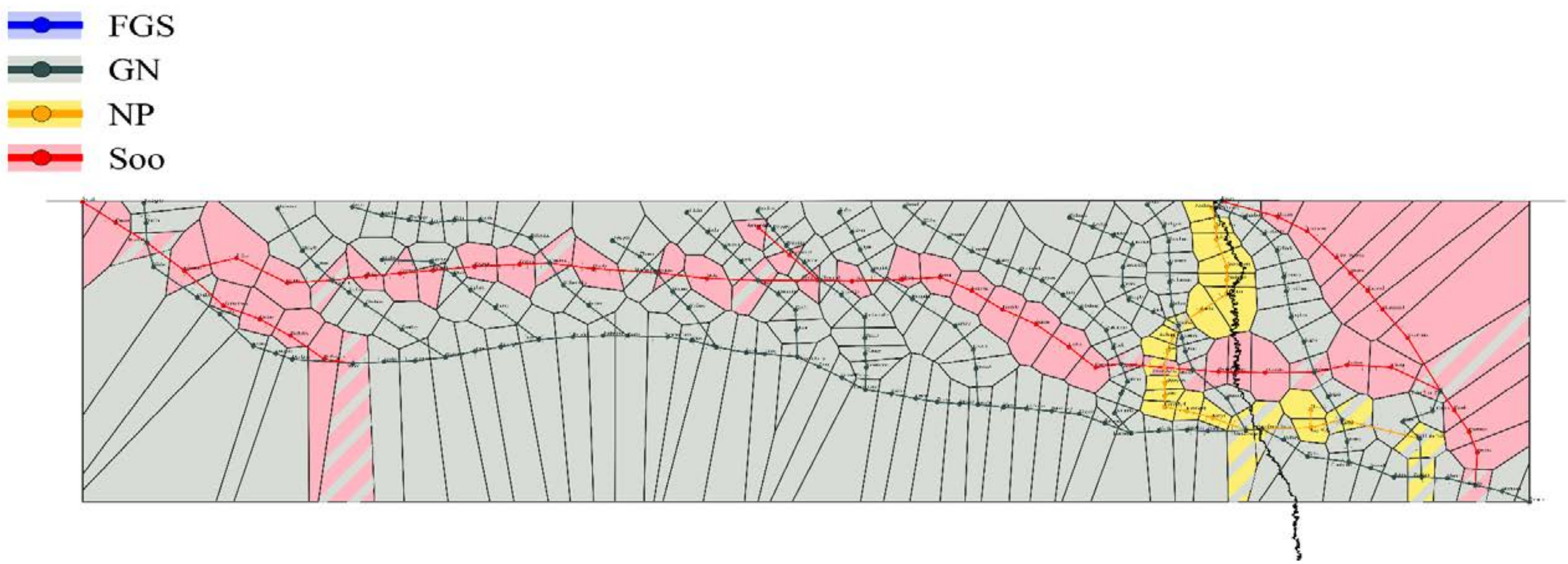


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Figure 7a: Population Indexes: Railroad War Towns, Railroad War Counties, and GN Mainline Counties

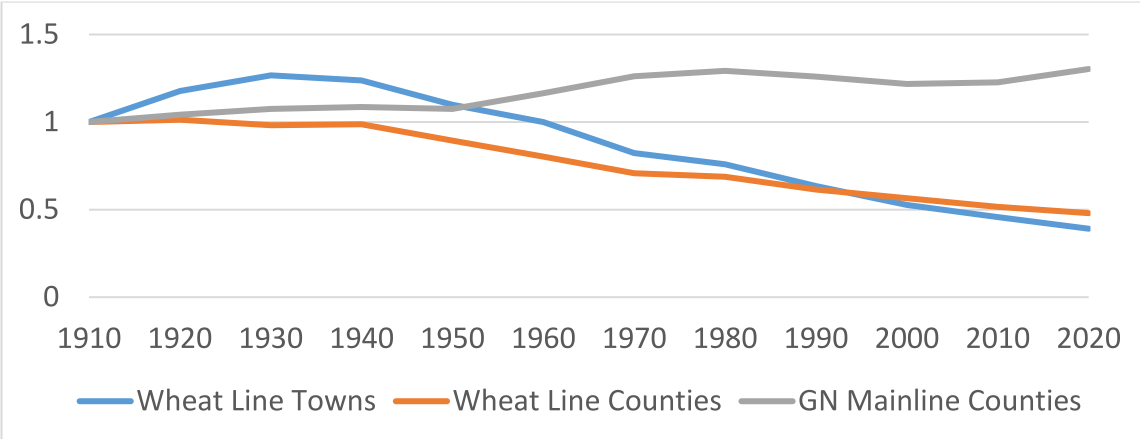


Figure 7b: Railroad War Town Total Populations by Founding Railroad

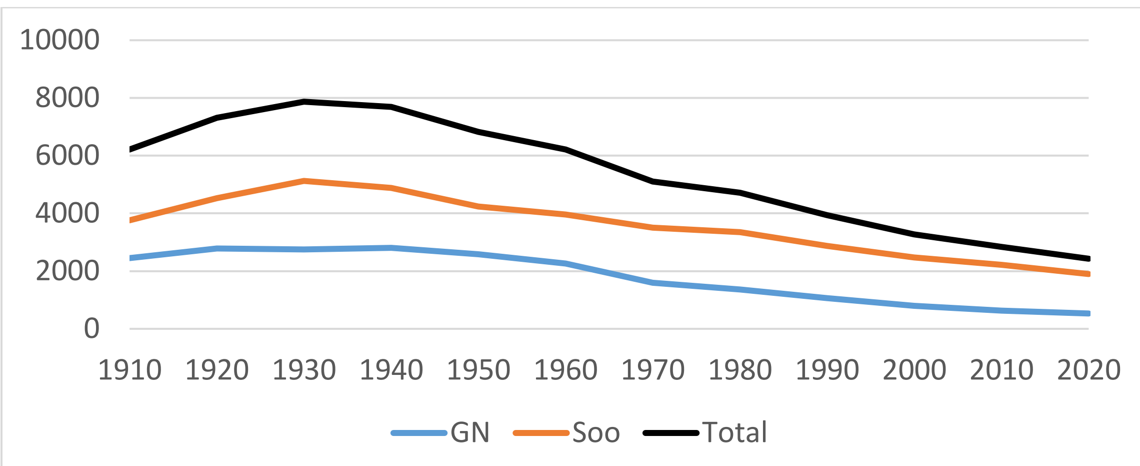
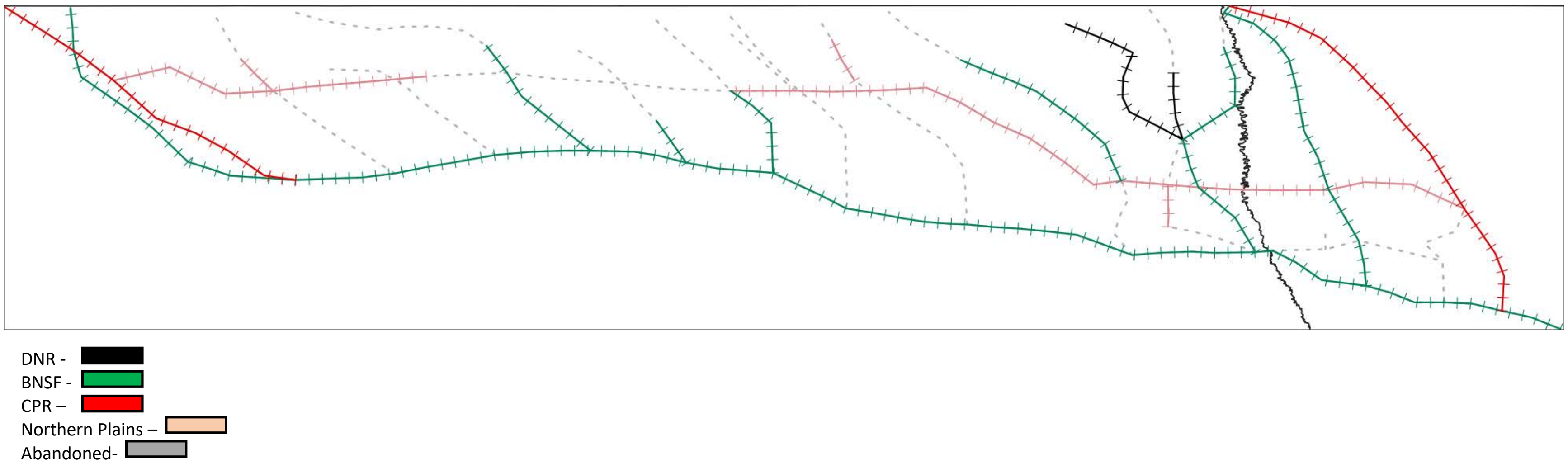


Figure 8: Railroads of the Study Area Today



APPENDIX

Figure A1: Comparison of Weighting Functions for Effective Catchment Area Computation

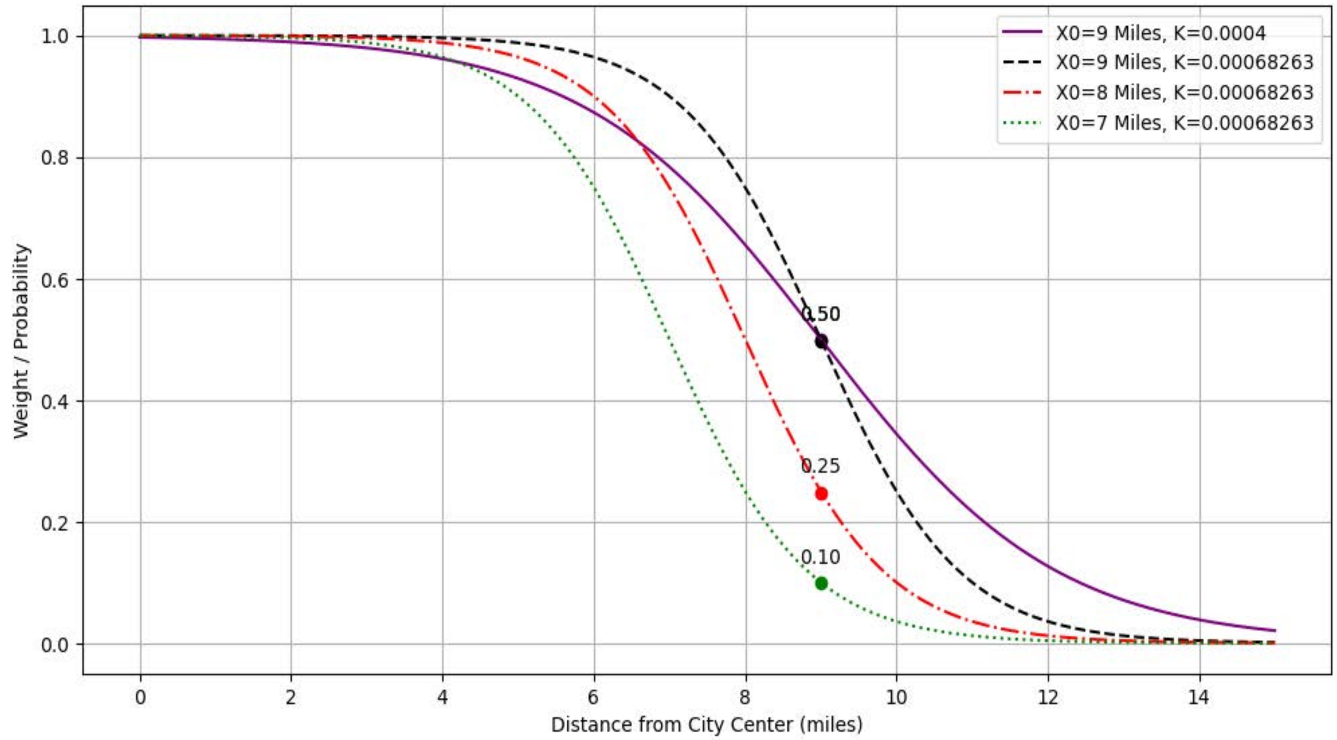


Table A1: Calculated Change in GN's Catchment Area (mi^2) for its Responses to Wheat Line, by Weighting Function

			Weighting Function				
Project	Miles	Towns	Uniform to 9-mile hard limit	0.1 at 9 miles	0.25 at 9 miles	0.5 at 9 miles	0.5 at 9 miles, slower decline
Maxbass (new line)	45	5	532	475	512	520	463
Antler (extension)	13	2	135	107	109	105	93
Dunseith (new line)	42	5	479	448	498	523	468
FGS (purchase)	23	4	320	318	349	371	356
Hansboro (extension of FGS)	42	6	412	360	351	330	311
Hansboro Full (FGS + extension)	65	10	732	678	700	702	667
Sarles (extension)	20	3	209	211	223	227	212
Added towns on existing lines	N/A	7	154	127	106	90	94