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Railroad Movement of Frac Sand in the U.S.: Costs and Tariffs

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NOTE: Unless explicitly stated otherwise, weights are given in tons of 2000 pounds, **not** metric tonnes of 2205 pounds (1000 Kg.). Distances given are in miles where one kilometer = 0.621 miles. Values are stated in US$ of the year indicated or in US$ of 2013 where so indicated. The terms "freight car" and "wagon" are used interchangeably.

Summary of Conclusions from Publicly Available Data

A rough summary of the data suggests that, in the U.S., sand traffic on the Class I Railroads:

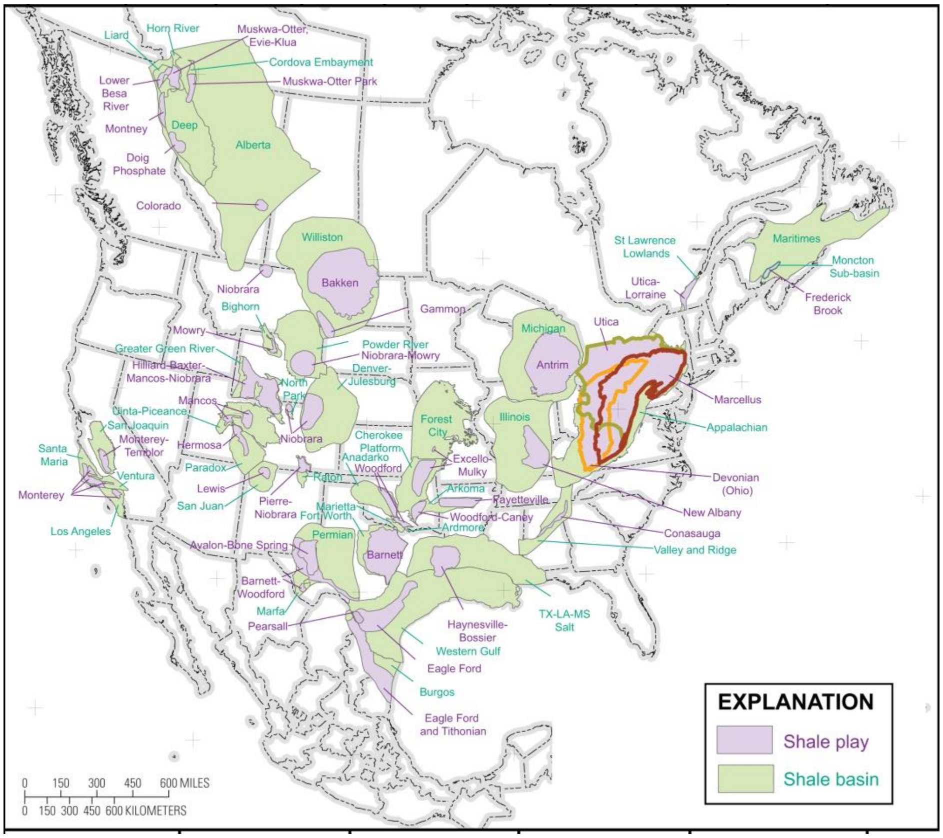
- Had an average carloading of about 100 tons.
- Moved between 420 and 450 miles, though frac sand probably has a longer haul.
- Had an average variable cost/ton-mile of 2.7 US cents.
- At that length of haul, had an average actual revenue/ton-mile of about 4.8 US cents. This is based on contract tariffs as the best indication and uses the 2013 ratio of masked to actual revenue/ton-mile.
- Traveled at a ratio of actual tariff to variable cost of about 177.5 percent.
- An alternative calculation from other STB statistics suggests that industrial sand (mostly frac sand) moves at a ratio of revenue/variable cost of 168.3 percent, in close agreement with the ratio of 177.5 percent given above.
- Two published tariffs originating in Wisconsin going to separate destinations in Texas for frac sand by the Union Pacific Railroad for a 1000 ton movement over 1316 to 1378 miles suggest a tariff of 4.33 to 4.48 US cents/ton-mile in shipper-owned wagons and 4.79 to 4.98 US cents in railroad-owned equipment.

This is the best that can be concluded from publicly available information and information provided on request for public use within the resources provided for this study.

Introduction: Frac Sand Profile

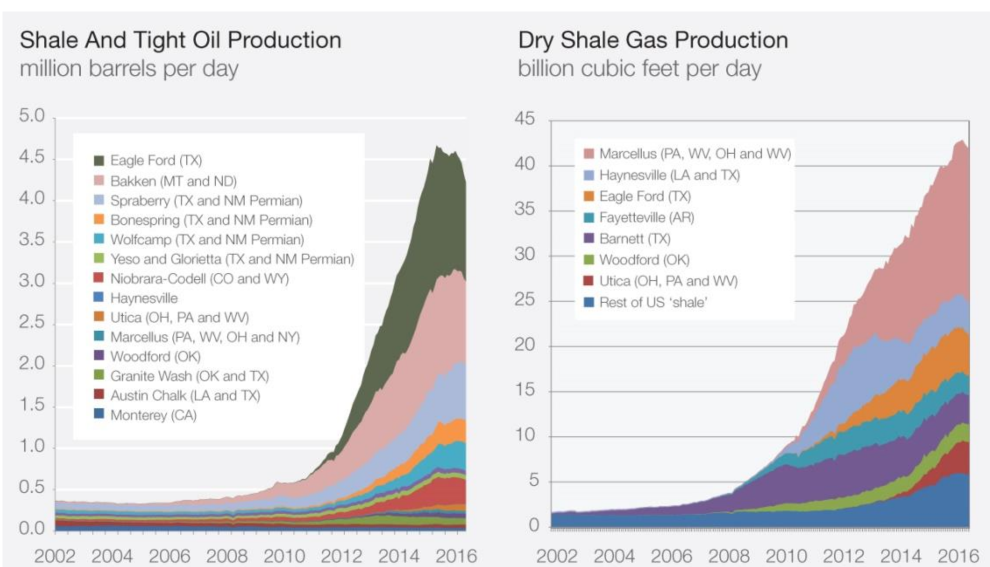
Hydraulic Fracturing (Fracking) has been a revolutionary innovation in production of crude oil and natural gas in the U.S. and elsewhere in the world. Though hydraulic fracturing originated more than 50 years ago, its use has grown rapidly as the industry has had to shift from the original, easily recoverable oil and gas resources to fields ("Plays") where the gas or oil (most fracturing is used to produce gas, though the approach also works for some oil reserves) is bound up in "tight" shale formations where the gas or oil is not easily released.

Figure 1 shows the significant shale plays in the lower 48 states of the U.S.



Source: Brady and Wilson 2015

Figure 2 shows the production of shale oil and gas in the U.S. between 2002 and 2016.



Source:API 2017

Fracking has become an increasingly sophisticated technology, but the basic approach depends on three innovations: very accurate assessment of geological formations permitting accurate mapping of reserves by type and location; precision well drilling, including horizontal drilling, so that the well piping is located precisely and is exposed to large areas of the shale; and fracturing of the shale to increase the release of oil or gas.

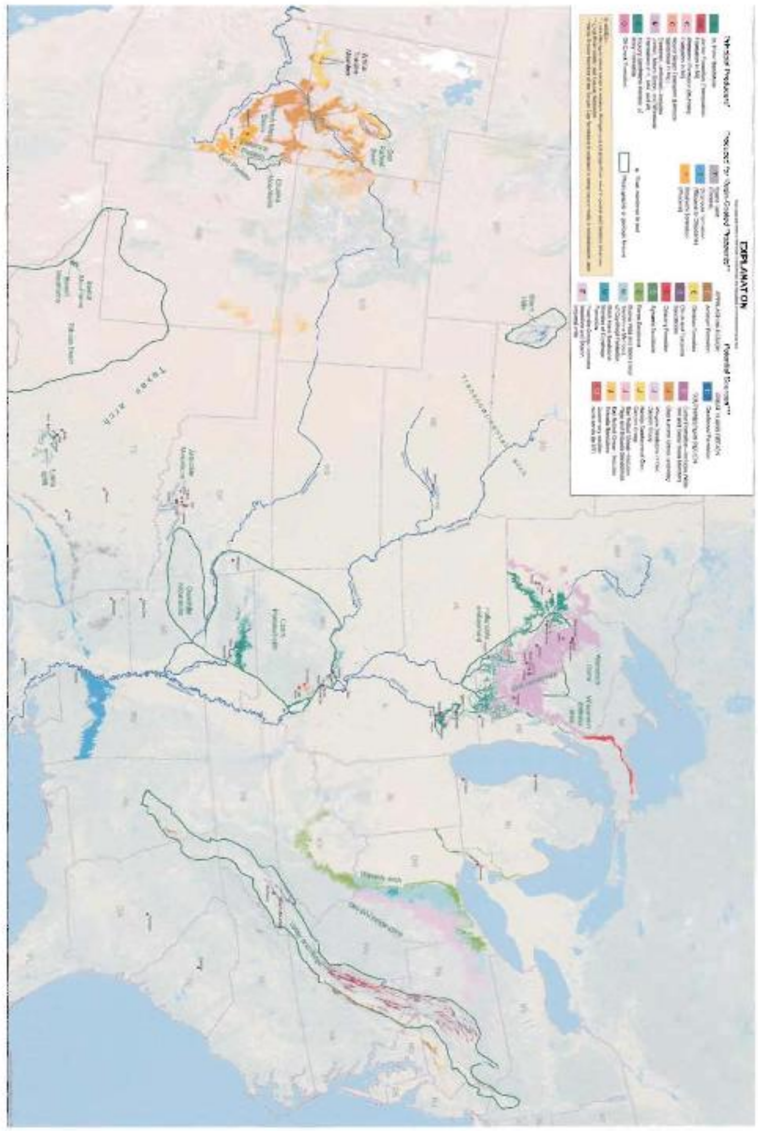
Fracking technology has also evolved greatly over the past 50 years. In simple terms, it involves injection of a fluid at very high pressures that causes the shale to fracture and propping the fractures open so that gas or oil can flow after the fracking fluid is withdrawn.

The fluid used is mostly water with a small percentage (0.5%) of chemical additives that act to improve the fracturing effect and to enhance flow afterward. The propping agent ("proppant") has mostly been sand, though recent technology has added coated sand and manufactured ceramic materials as proppant options. On average, the proppant amounts to 9.5 percent of the material injected[1] and about 230 tons of sand are injected in each initial fracturing operation.[2]

"Frac sand is a specialized type of sand that is added to fracking fluids that are injected into unconventional oil and gas wells during hydraulic fracturing (fracking or hydrofracking), a process that enhances petroleum extraction from tight (low permeability) reservoirs. Frac sand consists of natural sand grains with strict mineralogical and textural specifications that act as a proppant (keeping induced fractures open), extending the time of release and the flow rate of hydrocarbons from fractured rock surfaces in contact with the well bore."[3]

Frac sand is produced in a number of areas of the U.S. as shown in Figure 3.

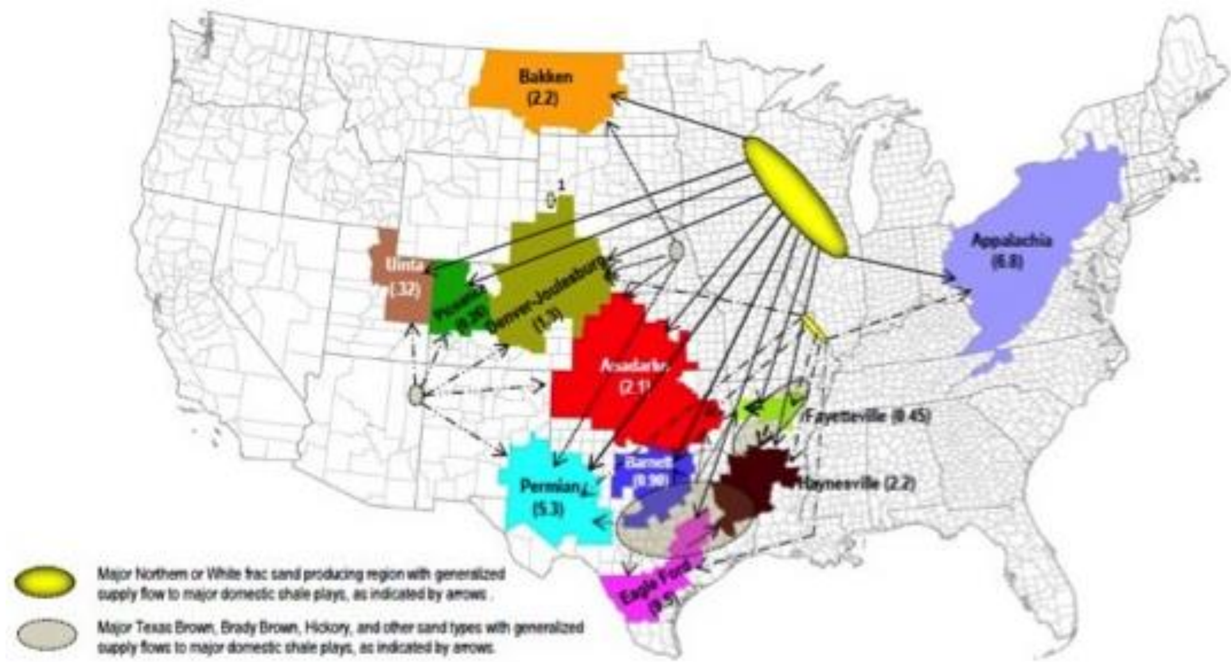
[1] API 2017
[2] Brady and Wilson 2015, page 55.
[3] Benson and Wilson 2015, abstract, page 1. This source contains an excellent description of Frac sand specifications and production in the U.S.



The major producing area is the upper mid-west, mostly Wisconsin, because of the high quality of the natural sand deposits. This sand is called "Northern White," or "Ottawa" sand and it accounts for about 70 percent of all sand used as proppant in the U.S[4] Another sand source is "Brown" or "Brady" sand produced mostly in Texas or Oklahoma.

Figure 4 shows the shipment pattern of these sands.

[4] Brady and Wilson 2015, page 53.



1 - Developing

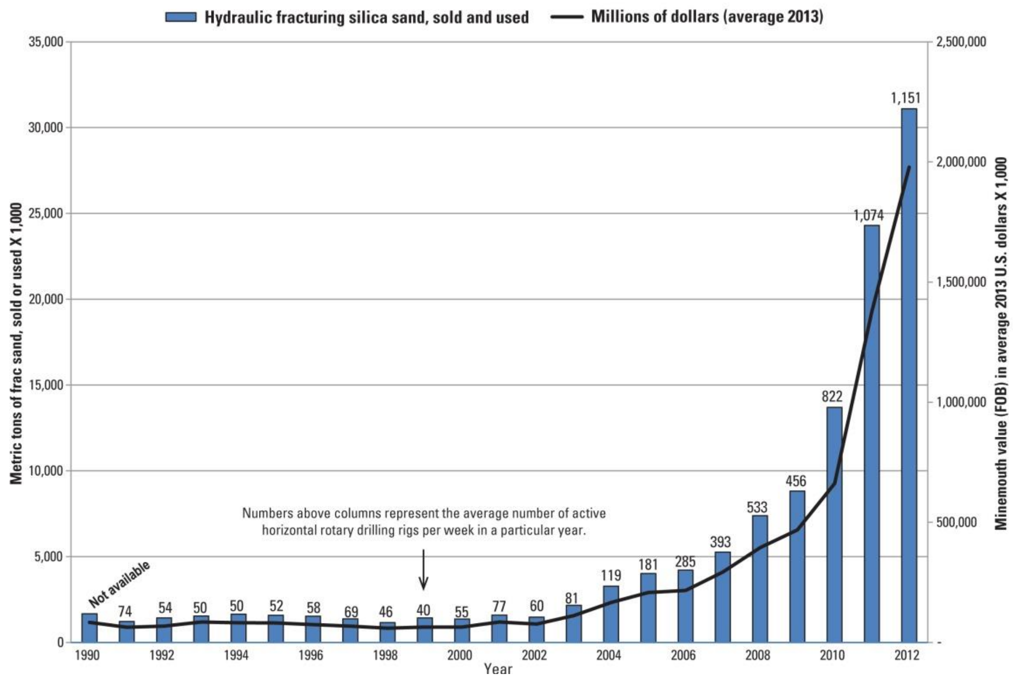
Table 1 shows the production and consumption of frac sand by state.

Table 1

Production and Consumption of Frac Sand in 2013

Major Shale Producing Area	States or Regions	Million tons of frac sand consumed	Percentage share of total frac sand consumed	Est. frac sand share of total proppants
Eagle Ford-Woodbine play	TX	9.50	30.4	95
Appalachia (inc Marcellus)	PA, NY, OH, WV	6.80	21.8	100
Permian Basin	NM, TX	5.30	17.0	90
Bakken play	MT, ND	2.20	7.0	69
Andarko Basin	Ks, OK, TX	2.10	6.7	91
Denver-Julesburg	CO, KS,NE, WY, SD	1.30	4.2	98
Haynesville-Brown Dense play	LA, TX	1.30	4.2	93
Barnett play	TX	0.90	2.9	99
Fayetville play	AR	0.45	1.4	100
Uinta Basin	UT	0.32	1.0	89
Piceance Basin	CO	0.26	0.8	96
Other	Various	0.83	2.7	91
Total		31.26	100.0	92

Figure 5 shows the tons of frac sand used, value of frac sand and the number of drilling rigs in operation from 1990 through 2012.[5]



Because of its more rigid specifications, frac sand is more valuable than other sand products. Estimates of value vary by source and year. In 2013, sand and gravel for construction had an estimated value of $7 ton, whereas industrial silica sand was valued at around $28/ton and frac sand had an estimated value between $50/ton and $87/ton.[6],[7] For perspective though, the average value of thermal coal in the U.S. has ranged from about $40/ton to $70/ton since 2012, so frac sand is not a particularly high-value commodity when compared to some of the other commodities carried by trucks and railways.[8] In fact, the value of frac sand is relatively low and the length of haul sufficiently long that railroads dominate the movement of frac sand (except in limited cases where barges can compete). One of the advantages that Wisconsin has is that it is well served by railroads, notably the Canadian National (CN), Canadian Pacific (CP) and Union Pacific (UP) railroads.[9] These systems all have connections with the CSX, Norfolk Southern (NS) and BNSF railroads to handle deliveries of the sand. Texas is also served by two major railroads and a number of regional and short line railroads.[10]

Railroad Costing and Pricing in the U.S.

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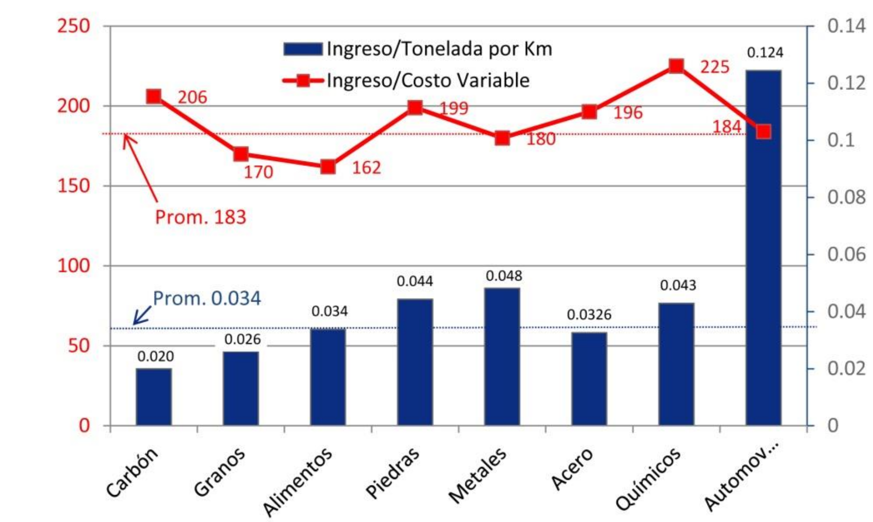
[5] Brady and Wilson 2015, page 56.
[6] Benson and Wilson 2015 contains and excellent description of Frac sand specifications and production in the U.S.
[7] USGS 2016, pages 66.11 and 66.12.
[8] Infomine 2017.
[9] Both Canadian railroad companies have extensive operations in the U.S.
[10] See, for example, Railroad Information Services, DeskMap Systems, "Professional Railroad Atlas of North America" for maps of the U.S. rail system.

Volumes can be (and have been) written on the subject of railroad traffic costing and pricing in the U.S. The approach to both subjects has evolved over the years along with changes in the U.S. transportation network, competition in the transportation market, and, in particular, regulation of railroads and trucking. Prior to 1981, railroad and truck regulation was quite rigid, and both traffic costing and pricing were treated mechanistically. In 1980-1982, however, both the rail and trucking markets were deregulated, and railroads were given broad freedom to calculate their costs and set their prices in accord with market conditions, especially competition.

Railroad deregulation ("The Staggers Act") basically lifted regulatory controls over railroad tariffs, subject to relaxed limits that apply only when railroads have adequate earnings and when the railroad(s) in question have "market dominance" (inadequate competition). One of the tests of the "reasonableness" of a rail tariff is to calculate the ratio of the tariff to its "variable cost," where variable cost is a U.S. regulatory term of art that is meant to resemble "marginal" cost as used in economic theory. In application, what this means is that a railroad tariff should be above variable cost (it would be irrational and potentially competitively predatory to charge less) at the lower end and should be "reasonable" on the upper end, which generally means that the contribution (surplus) above variable cost is maximized so long as the traffic is not too heavily burdened by the rate and the ratio of tariff rate to variable cost is not too high. The Staggers Act established a ratio of tariff rate to variable cost of 180 percent as being presumptively reasonable, but allowed individual ratios to go higher subject to the judgement of the regulator (the Surface Transportation Board, or STB) that the overall result did not unduly burden the movement of the traffic. Figure 6 shows the pattern of revenue/ton-mile and revenue/variable cost ratio of U.S. railroads for a broad set of commodities, showing how regulation is working in practice.[11]

Estructura de las tarifas de los ferrocarriles estadounidenses de carga y razón entre ingreso y costo variable

Dólares de 2012/tonelada por kilómetro;en rojo



Fuente: Cálculos realizados por Lou Thompson, y basados en STB, *Public Access Carload Waybill Sample.*

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[11] Source of Figure 6 is ITF 2015. This study is a good summary of comparative rail regulation in the U.S. Canada and (potentially) Mexico and has detailed background discussion of rail costing and pricing issues.

In addition, the Staggers Act explicitly allowed railroads and shippers to enter into voluntary contracts that could specify a contract period, minimum volumes, specialized equipment, service conditions, shipper investment in freight wagons or handling facilities, and tariff guarantees and discounts among many other possibilities. Because the contracts are voluntary (neither side is required to enter into the contract), they are entirely confidential and none of the terms are available to the public, though the STB may have access if required in a regulatory proceeding.

As discussed in a study of Mexican rail regulatory issues (ITF 2015), U.S. regulation is obviously dependent on the ability to actually measure the costs of the traffic in question and to judge the impact of a proposed rate on the movement of traffic. Neither is simple: in practice, theoretical and practical limitations mean that they can only be approximated. This bears repeating – *every calculation of rail traffic costs is inherently subject to a range of uncertainty, and every relevant tariff for frac sand traffic is based on railroad and shipper negotiation as to market competitive conditions where neither actually knows the actual facts, especially as viewed by the other. To make things more difficult, because a major part of all frac sand traffic moves under contract, the terms of actual frac sand tariffs are kept confidential by both railroad and shipper/receiver.*

Traffic Costing

Measuring the "cost" of a particular piece of railroad traffic is inherently questionable for two main reasons. Railroads not only have direct costs (such as train fuel or crew costs) that could be specifically attributed to a particular piece of traffic; they also have "joint and common" costs (such as signal operations or empty-return wagon travel) that are caused by operations in general, but cannot be accurately attributed to a particular piece of traffic. Equally important, railroad accounting systems rarely collect or report cost information in the forms needed for direct cost attribution.

As a result, even variable costs are approximations to various degrees of accuracy depending on the importance of the traffic being costed: estimating the cost of a shipment of a few wagonloads would call for use of more generalized averages, costing a potential contract tariff for multiple unit-train movements would be based on very detailed analyses using the actual wagon type, train length, axle load, topography, etc. In reviewing a tariff dispute, the STB will use costing methods appropriate to the case under consideration. Cases involving large volumes under contract will normally involve very specific information, will be very costly to adjudicate, and will not be readily available for public review. In such cases, the railroads will use an internal costing model that reflects the particular costs faced by the railroad in the movement in question.

The information available to the public for rail traffic costing is based on a very general, aggregate model developed by the STB using the Uniform Rail Costing System (URCS) as specified by the STB. In general terms, the STB uses the data in URCS to perform a series of multivariate linear regressions of cost categories (fuel, labor, etc.) against measures of volume (tons, wagon loads, ton-miles, etc.). The net result is a set of coefficients of variable cost against volumes involved.[12] Taken together, these coefficients give the overall estimate of “variable cost” for a particular movement.

This approach to costing originated with the predecessor regulator (The Interstate Commerce Commission, or ICC) and has evolved over many years, including a number of revisions implemented by the STB. It has been debated for many years, and there is essentially no reputable economist who will defend either the process or the result except when taken with a large dose of *caveat emptor*. With this said, it is the only publicly available source for traffic cost estimates, and the results are often used in the industry, albeit with considerable qualification.

Fortunately, traffic costing in the U.S. has a limited application: it only answers the question of how **low** can proposed tariffs go. That is, what is the floor under which even direct costs are not being covered or at which the railroad might be accused of predatory pricing to drive a competitor out of business. It can also serve as the beginning point for analyzing the upper limit of a tariff, but only as an indicator. For these purposes, an approximation is suitable.

Setting Tariffs

Tariff setting after the Staggers Act rapidly evolved from looking numbers up in a published tariff book to an exercise in which the railroad marketing department tries to estimate how high the tariff can be set while still carrying the traffic. In the case of frac sand, the railroad has a sense of the FOB mine head price and an estimate of how much the petroleum producer would be willing (or able) to pay for the sand delivered at the well site. The difference is the maximum tariff that could be set. Setting the actual tariff then becomes a negotiation between railroad and shipper on price and contract terms with the final result being determined by many factors including contract period, volumes, period of commitment, shipper versus railroad investment, and competition among many other factors.

It is common in the U.S. for a given shipment to be subject to at least some competition between railroads, either on parallel routes (parallel competition) or competing sources of supply using competing railroads (source competition). For example, there are over 50 sand mines in Wisconsin that might supply a given well in the Marcellus Play or Texas, and wells in Texas can choose between “Northern White” or “Brady” sand depending on delivered cost and performance tradeoffs. Tariffs will obviously be lower where effective competition exists and higher where only one source of supply or one railroad is involved (“market dominance”). Because of the impact of competition (or lack thereof), movements of frac sand that have very similar physical conditions of volume and distance may well have significantly different tariffs and the averages presented below have to be taken in this context.

The Numbers

As discussed above, the actual costs and revenues for frac sand movement by rail in the U.S. are confidential and closely guarded. We can make estimates, but they will necessarily be subject to a range of uncertainty.

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[12] Strictly speaking, the result is an estimate of the first derivatives of the cost categories as a function of the volume measure. This slope coefficient gives an estimate of the rate at which the cost category varies as volume changes.

There are a number of sources of publicly available information.[13] One important source is *Statistics of Class I Railroads*, produced by the STB based on an annual reporting requirement that all Class I Railroads must meet.[14] *Statistics of Class I Railroads* includes a wide range of accounting and operational data for each railroad and for the Class I industry including carloads originated, tons originated, and actual revenues for a number of broad commodity groupings. Critically for the purposes of this report, however, ton-miles are not reported, so tariff comparisons per ton-mile by commodity group are not possible. *Statistics of Class I Railroads* has been published in essentially its existing form for nearly one hundred years and is an essential source of industry data.

A second source of information is the "Public Use Carload Waybill Sample" (CWS) developed and reported by the STB. Each shipment by rail must be accompanied by a shipping document -- a "Waybill" -- that records a number of facts about the shipment, including originating and terminating station, originating and terminating railroad (and any other railroads participating in the movement), commodity, wagon loads, tons, and revenue, among a large set of other accounting data. Each railroad furnishes the STB with a file of Waybills from which the STB selects a random sample (generally at the one percent level, but with the sampling rate adjusted to reflect the fact that unit trains, for example, will appear less frequently than single carloads) for further analysis. Because contract tariffs are confidential, the revenue on the waybill is "masked" (multiplied by an unstated factor) in a way known only to the reporting railroad and the STB when required. The resulting statistics are aggregated into broad commodity groups and made available for public analysis.

The STB also processes the CWS through a model that attaches a station-to-station distance to the shipment using a system network model and estimates the variable cost of the shipment using a simplified form of the URCS-based costing model. The final result is a set of shipments that have commodity, carloads, tons, variable cost, and masked revenue attached. Under some circumstances this work is made available to researchers, but normally only with the commodity aggregated at a broad level. This will be called the "costed CWS."

Railroads identify commodities by a seven digit "Standard Transportation Commodity Code," of STCC. For example, frac sand has the following codes:

- 1441311 Sand, fracking, 16/30 mesh
- 1441312 Sand, fracking, 20/40 mesh
- 1441313 Sand, fracking, 30/50 mesh
- 1441314 Sand, industrial, well fracture propping
- 1441316 Sand, fracking, 40/70 mesh
- 1441317 Sand, fracking, 100 mesh
- 1441318 Sand, Fracking, 12/20 Mesh
- 1441319 Sand, Fracking, 20/50 Mesh

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[13] McCullough and Thompson 2013 discusses the data sources and issues in detail. Among other issues, this paper developed the method used in Table 5 below, for "unmasking" contract tariff revenues at the two digit STCC level.

[14] Class I Railroads are defined as having annual revenues of more than $457.9 million. There are seven Class I Railroads (UP, BNSF, CSX, NS, CN, CP and KCS). Class I Railroads account for about 95% of the industry revenues. There are also 21 Regional Railroads and 546 small Local Railroads. See AAR 2017, page 3.

- 1441321 Sand, Fracking, 20/45 Mesh
- 1441322 Sand, Fracking, 30/70 Mesh
- 1441323 Sand, Fracking, 16/35 Mesh
- 1441324 Sand, Fracking, 23/50 Mesh

The STB cannot release data at this level of detail, partly because, with only a few Class I railroads, it might be possible for one railroad (or a smart analyst) to identify specific traffic flows along with the railroads and shippers involved. In addition, the sampling rate is far too small to permit a valid expansion to represent the overall traffic base. We will have to use a more composite commodity description.

We do have data at the two-digit STCC level (STCC 14) from two sources, *Statistics of Class I Railroads* and the costed CWS. STCC 14 is called "non-metallic minerals," and includes all versions of crushed stone, gravel, and sand, along with a minor amount for other non-metallic materials.

The data taken from *Statistics of Class I Railroads* are shown in Table 2, which shows for the period 2005 through 2015, for "account 537, crushed stone, gravel and sand" and "account 538, non-metallic minerals," carloads originated, tons originated, gross freight revenue ("gross" means before minor end-of-year accounting adjustments), tons/carload, and revenue/ton. Accounts 537 and 538 need to be added together to make up the full STCC 14. The freight revenue in this table has **not** been masked: it is taken from the financial books of account of the railroads. Ton-miles by commodity information are **not** available from this source. Table 3 contains the same information shown separately for the four largest Class I Railroads.

Table 2

STCC 14 Data taken from *Statistics of Class I Railroads*											
								Revised			
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Carloads Originated											
537. Crushed Stone, Gravel and Sand	1,072,568	1,116,643	1,051,168	994,823	777,821	917,562	960,254	1,019,429	1,118,148	1,310,531	1,272,101
538. Non-Metallic Minerals	415,489	353,443	346,391	330,359	275,892	299,198	302,549	259,853	265,788	272,290	249,082
TOTAL STCC 14	1,488,057	1,470,086	1,397,559	1,325,182	1,053,713	1,216,760	1,262,803	1,279,282	1,383,936	1,582,821	1,521,183
Tons Originated (2000 pounds)											
558. Crushed Stone, Gravel and Sand	104,874,464	106,565,467	104,094,954	99,981,895	78,170,993	92,967,697	97,943,673	104,356,244	116,148,578	137,705,620	134,753,324
559. Non-Metallic Minerals	40,822,503	34,305,074	33,460,934	32,369,923	27,226,317	29,557,777	29,845,957	25,727,564	26,094,853	26,955,718	25,011,442
TOTAL STCC 14	145,696,967	140,870,541	137,555,888	132,351,818	105,397,310	122,525,474	127,789,630	130,083,808	142,243,431	164,661,338	159,764,766
Gross Freight Revenue ($000)*											
581. Crushed Stone, Gravel and Sand	905,297	1,058,627	1,119,087	1,284,664	955,365	1,362,751	1,805,890	2,164,137	2,668,516	3,451,898	2,845,248
582. Non-Metallic Minerals	387,441	402,952	408,192	464,332	364,672	454,547	533,872	523,896	562,056	562,888	507,196
TOTAL STCC 14	1,292,738	1,461,579	1,527,279	1,748,996	1,320,037	1,817,298	2,339,762	2,688,033	3,230,572	4,014,786	3,352,444
Current US$ before year-end accounting adjustments (usually not large). **Actual, not masked**											
Tons/Carload											
537. Crushed Stone, Gravel and Sand	97.8	95.4	99.0	100.5	100.5	101.3	102.0	102.4	103.9	105.1	105.9
538. Non-Metallic Minerals	98.3	97.1	96.6	98.0	98.7	98.8	98.6	99.0	98.2	99.0	100.4
TOTAL STCC 14	97.9	95.8	98.4	99.9	100.0	100.7	101.2	101.7	102.8	104.0	105.0
Revenue/Ton											
537. Crushed Stone, Gravel and Sand	8.63	9.93	10.75	12.85	12.22	14.66	18.44	20.74	22.98	25.07	21.11
538. Non-Metallic Minerals	9.49	11.75	12.20	14.34	13.39	15.38	17.89	20.36	21.54	20.88	20.28
TOTAL STCC 14	8.87	10.38	11.10	13.21	12.52	14.83	18.31	20.66	22.71	24.38	20.98
Source, Surface Transportation Board (STB), "Statistics of Class I Railroads," years 2005 to 2015.											

Table 3					
Data Taken from the 2013 edition of *Statistics of Class I Railroads*					
	U.S.	**CSX**	**NS**	**BNSF**	**UP**
Carloads Originated					
Crushed Stone, Gravel and Sand	1,118,148	196,390	152,567	209,049	420,515
Non-Metallic Minerals	265,788	169,109	13,474	25,722	50,637
TOTAL STCC 14	1,383,936	365,499	166,041	234,771	471,152
Total Carloads Originated	28,830,139	4,870,005	4,930,738	9,169,327	7,236,025
Tons Originated (2000 pounds)					
Crushed Stone, Gravel and Sand	116,148,578	20,552,594	15,880,118	22,182,264	44,301,332
Non-Metallic Minerals	26,094,853	17,258,210	1,297,864	2,386,520	4,515,157
TOTAL STCC 14	142,243,431	37,810,804	17,177,982	24,568,784	48,816,489
Total Tons Originated	1,757,650,374	293,401,896	262,047,594	557,103,909	449,215,613
Gross Freight Revenue (US$000)					
Crushed Stone, Gravel and Sand	2,668,516	288,339	314,463	612,967	1,176,719
Non-Metallic Minerals	562,056	176,268	66,499	112,578	159,288
TOTAL STCC 14	3,230,572	464,607	380,962	725,545	1,336,007
Total Revenue	72,055,862	11,347,538	10,970,929	22,096,785	21,573,841
Tons per Carload Originated					
Crushed Stone, Gravel and Sand	103.9	104.7	104.1	106.1	105.4
Non-Metallic Minerals	98.2	102.1	96.3	92.8	89.2
TOTAL STCC 14	102.8	103.4	103.5	104.6	103.6
Revenue per Ton Originated (US$/ton)					
Crushed Stone, Gravel and Sand	22.98	14.03	19.80	27.63	26.56
Non-Metallic Minerals	21.54	10.21	51.24	47.17	35.28
TOTAL STCC 14	22.71	12.29	22.18	29.53	27.37
All Carloads Originated	41.00	38.68	41.87	39.66	48.03
Revenue per Carload Originated (US$)					
Crushed Stone, Gravel and Sand	2,387	1,468	2,061	2,932	2,798
Non-Metallic Minerals	2,115	1,042	4,935	4,377	3,146
TOTAL STCC 14	2,334	1,271	2,294	3,090	2,836
Total Revenue for All Traffic	2,499	2,330	2,225	2,410	2,981
Source: STB, Statistics of Class I Railroads, 2013					

Tables 2 and 3 taken together yield several useful pieces of information. First, an average loading per car in the 100 to 105 tons/carload range is probably a good representative number to use. Second, though, in the absence of ton-miles, the revenue/carload and revenue/ton numbers may not be comparable because the average length of haul could well be different among railroads and over the years.

Table 4 displays data for STCC 14 for the period 2005 to 2013 (latest available year that has been processed) as furnished by the STB from the costed CWS, and Table 5 shows the ratios taken from Table 4.

Table 4

STCC 14 Data Taken from the STB costed CWS

	2005	2006	2007	2008	2009	2010	2011	2012	2013
TOTAL CARLOADS OF TRAFFIC ORIGINATED									
Carloads Total	1,776	1,766	1,685	1,446	1,194	1,354	1,394	1,472	1,578
Contract Carloads	1,167	999	920	890	777	893	952	1,041	1,109
TOTAL TONS OF TRAFFIC ORIGINATED									
Tons Total	175,610	173,321	168,173	142,134	117,296	133,936	135,357	145,160	156,016
Contract Tons	115,465	97,794	90,190	86,094	75,262	87,014	91,289	101,221	108,164
TON-MILES									
Ton-Miles Total	46,482	47,901	48,405	45,307	36,245	47,146	55,326	60,120	71,193
Contract Ton-Miles	29,857	26,401	25,673	25,000	20,450	28,104	34,670	37,150	45,161
MASKED REVENUE!									
Revenue Total	1,641	1,810	1,897	2,064	1,686	2,301	2,894	3,289	3,918
Contract Revenue	1,112	1,060	1,062	1,227	1,042	1,468	1,902	2,141	2,627
VARIABLE COST									
Variable Cost Total	1,000	1,035	1,129	1,211	918	1,205	1,572	1,694	1,908
Contract Traffic Var. Cost	642	587	615	707	563	754	1,017	1,086	1,239

Source: STB, costed version of "Public Use Carload Waybill Sample," provided by request to author

Table 5

Ratios Computed from the STB costed CWS for STCC 14 only

		2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Tons/Carload STCC 14										
	Total	98.9	98.2	99.8	98.3	98.3	98.9	97.1	98.6	98.9
	Contract	98.9	97.8	98.0	96.7	96.9	97.4	95.9	97.2	97.6
Ton-miles/ton STCC 14										
	Total	265	276	288	319	309	352	409	414	456
	Contract	259	270	285	290	272	323	380	367	418
Masked Revenue/ton-mile STCC 14										
	Total	0.035	0.038	0.039	0.046	0.047	0.049	0.052	0.055	0.055
	Contract	0.037	0.040	0.041	0.049	0.051	0.052	0.055	0.058	0.058
Variable Cost/ton-mile STCC 14										
	Total	0.022	0.022	0.023	0.027	0.025	0.026	0.028	0.028	0.027
	Contract	0.022	0.022	0.024	0.028	0.028	0.027	0.029	0.029	0.027
Masked Revenue/Variable Cost Ratio in Percent for STCC 14										
	Total	164.2	174.8	168.0	170.3	183.7	191.0	184.1	194.1	205.4
	Contract	173.0	180.6	172.7	173.6	185.0	194.6	187.1	197.2	212.0
Computed ACTUAL Revenue/Ton-mile										
	Total Traffic	0.028	0.031	0.032	0.039	0.036	0.039	0.042	0.045	0.045
	Ratio: Masked to Actual	1.27	1.24	1.24	1.18	1.28	1.27	1.24	1.22	1.21

Source: Table 4 and Table 2 (for computed actual revenue/ton-mile)

Table 4 shows the STB's estimates for STCC 14 of: carloads originated, tons, ton-miles, revenue (which is masked), and variable cost. These numbers are shown separately for all STCC 14 traffic and for STCC 14 traffic that is traveling under a contract (about 70 percent of tons travel under contract). Table 5 shows separately for all STCC 14 traffic and for STCC 14 traffic traveling under contract: tons/carload, ton-miles/ton, revenue (masked) per ton-mile, variable cost/ton-mile and the ratio of revenue (masked) to variable cost.

Tables 4 and 5 bring us closer to the bottom line. In 2013, for STCC 14 traffic, the average car loading for contract and total traffic was about 100 tons/carload and was stable over the period. Average length of haul was 418 miles for contract traffic and 456 miles for all traffic, but increased significantly over the period. Since we know that frac sand traffic has grown rapidly since about 2009 (see Figure 2), the increase probably indicates that frac sand has a longer length of haul than the overall STCC 14 average. The average masked revenue/ton-mile was 5.5 US cents for all traffic versus 5.8 US cents for contract traffic. The significant increase over the period indicates that the average revenue for frac sand might be somewhat higher than the overall average for STCC 14. The variable cost was around 2.7 US cents/ton-mile for both types of traffic, and that remained nearly stable over the period, indicating that the cost (as opposed to revenue) of hauling frac sand may not be significantly different than the average for STCC 14. The ratio of masked revenue to variable cost was 205 percent for all traffic and 212 percent for contract traffic, though these ratios increased significantly over the time period, again indicating that frac sand may have somewhat higher tariffs than the average for STCC 14. Table 5 also shows that the masked revenue on STCC 14 overall was about 20 percent higher than the actual revenue, indicating the impact of masked contract tariffs on the average tariff for STCC 14.

A rough summary of the data suggests that, in the U.S., overall sand traffic on the Class I Railroads:

- Had an average carload of about 100 tons.
- Moved between 420 and 450 miles, though frac sand probably has a longer haul.
- Had an average variable cost/ton-mile of 2.7 US cents.
- At that length of haul, had an average actual revenue/ton-mile of about 4.8 US cents. This uses the contract tariff as the best indication of real conditions and uses the 2013 ratio of masked to actual revenue/ton-mile.
- Traveled at a ratio of actual tariff to variable cost of about 177.5 percent.

There are two additional public sources about frac sand at a level well below the STCC 14 level. The STB publishes an "Expanded Stratification Report," carloads, tons, revenue (masked) and the computed variable cost but not, unfortunately, the computed ton-miles. It is possible to estimate the overall weighted average ratio of revenue/variable cost: the result, 168.3 percent, is closely in agreement with the estimate above for all STCC traffic of 177.5 percent.

A detailed study of public railroad tariffs for frac sand would be complex and is beyond the scope of this study. It is interesting, though, to look at the UP tariff for STCC 1441312 (Sand, fracking, 20/40 mesh). This tariff is available because the UP serves the mines in Wisconsin and carries the sand in single line service to destinations in Texas. Two examples are available:

- 1000 ton movements of STCC 1441312 from New Auburn, WI to Odessa, TX, a distance of 1316 miles by road (rail distance would probably be ten percent further). The tariff for one carload in shipper-owned wagons would be $6339 plus $142 in fuel surcharge. In railroad-owned wagons the tariff would be $7060 plus $142. This is a public tariff, so revenue is not masked. This would then be 4.48 US cents per ton-mile in shipper-owned wagons and 4.98 US cents per ton-mile in railroad-owned wagons.

- 1000 ton movements of STCC 1441312 from New Auburn WI to Three Rivers, TX, a distance of 1378 miles. In shipper-owned wagons, this would cost $6418/wagonload plus $145 for fuel surcharge. In railroad-owned wagons, the similar charge would be $7118 plus $145. Using the same 10 percent allowance for circuity, this would equate to 4.33 US cents per ton-mile for shipper-owned wagons and 4.79 cents per ton-mile for railroad-owned equipment.

Both of these are in close agreement with the 4.8 US cents per ton-mile estimated above for contract tariffs on STCC 14 overall, though the length of haul, over 1300 miles, is significantly longer than the average for STCC 14 and this is not a contract tariff for unit train movement. It is possible that a contract tariff for 10,000 ton unit train shipments would be somewhat lower.

This is the best that can be concluded from publicly available information and information provided on request for public use.

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