Strategic Market Analytics for Fracking

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Abstract

This project prioritized fracking sites for an offshore gas company, which has limited funding. The prioritization goal is based upon 3 criterias - economic, geospatial, and media sentiment. Each of the criterias includes several sub criterias as well. In this analysis the biggest challenge was analyzing qualitative data, and in order to do so, we utilized the Analytical Hierarchy Process, which helped us find the best results that meet our goal. After applying the methods to analyze multiple drilling sites in Colorado, 18 fracking sites are successfully selected and prioritized. The methodology can be applied to other states and countries to prioritize fracking sites. It is important to note that the framework used for this project is modifiable based on clients' needs; the prioritization criterias explained above were chosen specific to our client's needs.

Executive Summary

We successfully prioritized 18 fracking sites from 643 exciting wells in state Colorado based on ecological, economic and sentiment elements. During the process, unstructured data and the lack of available data are the main issues that we faced. We conduct the final analysis by four steps. Firstly, we use QGIS to load shapefile and applied differencing Algorithm. Then, we use GRASS GIS and Geospatial Analysis to find the useful quantitative data. Finally, we use AHP to select optimal drilling sites. The selected 18 fracking sites out off 643 Drilling sites in Colorado are far from park conservation areas, water conservations areas, urban areas, or earthquake faults and are close to the main highways. Wells with these characteristics will impose effect on urban areas and save transportation costs. In AHP method, ecological, sentimental and economical elements are assigned different weight and thus play different importance in determining drilling sites.

Introduction

The objective of this prioritize drilling on existing fracking sites. Prioritization often becomes a highly subjective and intuitive notion with subjective discrete metrics based on a variety of criterias. This project focuses on a mathematical approach to prioritization by transforming the discrete and intuitive metrics into a quantifiable scale in order to generate a prioritization vector. It is important to understand that prioritization must be performed based on specific underlying criterias, and different criterias will create different priority metrics. Upon consulting with clients and external resources this project is driven by three underlying criterias: *Ecological, Logistical and Sentimental*. Here, *Ecological* criteria focuses on environmental impact and are subsequently formed from sub criterias: *Faults, Groundwater reserves, and Park conservation areas*. Similarly, *Logistical* criteria is *proximity to urban areas, and highways*. Lastly, *Sentimental* criteria looks at *Local Media Reaction* rather than the conventional public sentiment, which can be often biased and misleading for the purposes of this project.

Given the recent success of the U.S. fracking industry, it may be tempting to ask why prioritize a specific site if an organization already has the geological survey results. One must note that this is a *Simulated Consulting Project*, where the team has been hired to advise an offshore gas company ("client") looking to expand its business to the U.S. fracking market due to its recent success and quick turnover. However, the client has limited funding available this fiscal year, and as such have hired our team to provide advisory in prioritizing drilling sites, in order to allocate its limited funding effectively. The advisory contract has the possibility of becoming a full contract based on the success of the prioritization proof of concept.

Our project framework is based upon *Ecological, Logistical,* and *Sentimental* factors. In order to drive the proof of concept of our prioritization metrics, the project focuses on applying the underlying framework to one state ("*Colorado*"). Upon successful application and effectiveness within Colorado, the client may choose to expand the scope to other states or nationwide. However, for this project we will only be focusing on the state of Colorado.

The results are consequential to any interested party. Within Colorado, we started with 643 wells and upon applying our framework we were able to filter out top 18 sites. Then we used our quantifiable prioritization method to develop a priority vector for the remaining 18 sites. The final results are deployed as a layer, which can be superimposed on *Google Maps / Earth* and as such requires no deployment costs. Currently the tool break the process into two steps (which can be modified based on client's requirements):

1. Filter Sites
   a. Based on distance to (Faults, Groundwater reserves, Park conservation areas, Urban Areas, Highways)
2. Prioritize filtered sites
   a. Using Analytical Hierarchical Process (AHP) - a framework to

transform qualitative subjective data to quantitative while maintaining consistency.

The framework used for this project can be relevant to a variety of stakeholders. In addition to an existing gas company looking to prioritize drilling sites, landowners may find it highly relevant to value their ownership. This can be taken one step further to real-estate investment firms, who may use the land value to develop investment opportunities..

Background

This project is centered around strategic market expansion of an offshore gas company to the US fracking industry. The client company has limited funding and our analytics team has been hired to provide advisory to the client in prioritizing drilling sites, in order to allocate their limited funding effectively.

Our project took a mathematical approach to generate a priority vector rather than relying upon subjective input. The scope of the advisory was narrowed to the state of Colorado as a proof of concept. Upon successful application the client holds the decision to expand the scope to other states or nationwide.

Our initial view of the project was that the implementation of analytical tools would be the most challenging part. However, gathering of data and then converting it into desired format has proven to be the hardest part. In brief, our initial (or expected) work plan went through significant changes after we had better familiarized ourselves with the essence of the problem.

Expectations:

- Issue: Analyzing data
- Abundant structured state and federal level data
- Prediction model

- Emphasis on numbers

Reality:

- Issue: Collecting data
- Missing and unstructured data on all levels
- Geospatial model
- Emphasis on visuals

After the change in approach we have decided to focus our efforts on creating an analytical tool that will be used by our client, as opposed to an analytical report containing only numbers and recommendations. First, this new approach would give more flexibility in regards to different applications. Second, it would be more user-friendly for people who do not necessarily have a technical or analytical background. Third, and perhaps most important, this new tool would serve as a foundation for a better analytical framework for the fracking industry. The said system, in our view, would be of great value for decision makers within the industry due to its simplicity and at the same time depth of analysis that can be gradually expanded in accordance with the needs of the client.

In other words, we started with a vision of a report that would only serve our clients once, but we ended up with an analytical tool that, if modified, can potentially fulfill given tasks over a long period.

Description of Work

Initial Data Exploration

Due to the lack of consistent data, we switched on to Geographical Information Systems (GIS). GIS data are normally in the form of Shapefiles (.shp). These shapefiles are based on longitude and latitudes / Zipcodes and can be projected upon a map using any GIS software.

For the purpose of this project we will be using two free GIS tools :

- Quantum GIS
- Grass GIS

As discussed previously we will be looking at the GIS data for the state of Colorado for the following aspects:

- Ecological :
    - Groundwater Reserves
    - Park conservation Areas
    - Earthquake faults
- Economic :
    - Urban Areas
    - Highways

Also, we will look at Sentiment data (discussed later in the report) for the selected wells in the state of Colorado

- Sentiments :
    - o Media Reaction

The following Screenshots show the five GIS dataset that are going to be used.

	field_code	dist_n_s	dir_n_s	dist_e_w	dir_e_w	qtrqtr	sec	twp	range	meridian	lat	long
1	31290	266	S	737	W	SWSW	23	4S	96W	6	39.681302	-108.142770
2	70830	906	N	1979	W	NENW	32	33S	65W	6	37.133130	-104.697080
3	5997	150	N	250	E	NENE	6	2S	43W	6	39.919190	-102.223750
4	70830	1221	S	1362	E	SWSE	4	35S	66W	6	37.023240	-104.781150
5	9000	1848	N	1880	E	SWNE	8	3S	60W	6	39.807140	-104.120670
6	57400	1935	S	658	E	NESE	18	1S	60W	6	39.962210	-104.134620
7	57400	555	N	763	E	NENE	19	1S	60W	6	39.955480	-104.134780
8	57400	1980	N	660	W	SWNW	17	1S	60W	6	39.966110	-104.129920
9	60000	1980	S	600	W	NWSW	24	3S	59W	6	39.774770	-103.942200
10	51385	800	N	2120	W	NENW	31	3S	59W	6	39.752330	-104.033030
11	68350	1980	S	660	E	NESE	32	4S	60W	6	39.658170	-104.118690
12	69755	1980	S	660	E	NESE	8	4S	62W	6	39.714935	-104.342843
13	48500	227	N	2334	E	NWNE	23	5S	61W	6	39.608210	-104.182320
14	77855	2640	S	660	E	SENE	20	33S	43W	6	37.156613	-102.279001
15	9850	660	N	1980	E	NWNE	2	35S	46W	6	37.030923	-102.567803
16	9850	660	S	1980	W	SESW	35	34S	46W	6	37.034551	-102.572323
17	9850	550	N	550	W	NWNW	1	35S	46W	6	37.031234	-102.559126
18	9850	2180	S	460	W	NWSW	12	35S	46W	6	37.009695	-102.559509
19	9850	1840	S	1840	E	NWSE	2	35S	46W	6	37.023225	-102.567319
20	9850	1780	N	2180	E	SWNE	1	35S	46W	6	37.027856	-102.550383
21	9850	610	S	2030	E	SWSE	1	35S	46W	6	37.019928	-102.549872

Fig 1.1 : Attribute table of all the Wells in the state of Colorado

	LGID	SOURCE	LGNAME	LGTYPEID	LGSTATUSID	ABBREV_NAM	MAIL_ADDRE	ALT_ADDRES	MAIL_CITY	MAIL_STATE	MAIL_ZIP
1	01045	Hybrid Adams 3-...	Central Adams C...	12	1	Central Adams C...	1641 California S...	c/o Miller & Assoc...	Denver	CO	80202
2	01021	Retrieved from A...	South Adams Co...	12	1	South Adams Co...	6595 E 70th Ave	PO BOX 597	Commerce City	CO	80037
3	18025	Douglas County ...	Centennial Wate...	12	1	Centennial Wate...	62 West Plaza Dr...		Highlands Ranch	CO	80129
4	35006	Larimer County f...	Estes Park Sanita...	10	1	Estes Park Sanita...	PO Box 722		Estes Park	CO	80517
5	03014	Arapahoe Public ...	Cherry Creek Vill...	11	1	Cherry Creek Vill...	7995 E Prentice ...	CRS of Colorado,...	Greenwood Village	CO	80011
6	03063	Arapahoe Public ...	Sheridan Sanitati...	10	1	Sheridan Sanitati...	390 Union Blvd., ...	c/o Collin Cockrel...	Denver	CO	80228
7	03070	Arapahoe Public ...	South Arapahoe ...	10	1	South Arapahoe ...	8390 E. Crescent...	c/o Clifton Larso...	Greenwood Village	CO	80111
8	03027	Arapahoe Public ...	Cherryvale Sanit...	10	1	Cherryvale Sanit...	1221 West Miner...	c/o Haynie & Co...	Littleton	CO	80120-4544
9	03061	Arapahoe Public ...	South Englewood...	10	1	South Englewood...	PO Box 2858	c/o Donald E. Ma...	Centennial	CO	80161
10	64129	Hybrid Arapahoe...	Southgate Sanita...	10	1	Southgate Sanita...	3722 East Orcha...		Centennial	CO	80121
11	03159	Arapahoe Public ...	Goldsmith Gulch ...	10	1	Goldsmith Gulch ...	8390 E. Crescent...	c/o Clifton Gunde...	Greenwood Village	CO	80111-2814
12	64080	Arapahoe Public ...	Inverness Water...	12	1	Inverness Water...	2 Inverness Driv...	c/o Mulhern MRE...	Englewood	CO	80112
13	64027	Hybrid Arapahoe...	Bow Mar Water ...	12	1	Bow Mar Water ...	1221 West Miner...	c/o Haynie & Co...	Littleton	CO	80120-4544
14	64077	Arapahoe Public ...	Holly Hills Water ...	12	1	Holly Hills Water ...	141 Union Boulev...		Lakewood	CO	80228-1898
15	03028	Arapahoe Public ...	City of Cherry Hil...	10	1	City of Cherry Hil...	3333 South Bann...		Englewood	CO	80110
16	65156	Hybrid Arapahoe...	Castlewood Wat...	12	1	Castlewood Wat...	4725 South Mon...	c/o Icenogle Sea...	Denver	CO	80237
17	03055	Arapahoe Public ...	Hillcrest Water & ...	12	1	Hillcrest Water & ...	7995 E Prentice ...	c/o Community R...	Greenwood Village	CO	80111
18	03057	Arapahoe Public ...	Mansfield Height...	12	1	Mansfield Height...	7995 E. Prentice ...	c/o Community R...	Greenwood Village	CO	80111
19	03105	Arapahoe Public ...	Cherry Creek Vall...	12	1	Cherry Creek Vall...	2325 S. Wabash ...		Denver	CO	80231
20	03038	Hybrid Arapahoe...	East Cherry Cree...	12	1	E. Cherry Cr. Vall...	6201 South Gun ...		Aurora	CO	80016
21	64110	Hybrid Arapahoe...	Platte Canyon W...	12	1	Platte Canyon W...	8739 West Coal ...		Littleton	CO	80123

Fig 1.2 : Attribute table of all the Water Reserves in the state of Colorado

	LGID	SOURCE	LGNAME	LGTYPEID	LGSTATUSID	ABBREV_NAM	MAIL_ADDRE	ALT_ADDRES	MAIL_CITY	MAIL_STATE	MAIL_ZIP
1	64119	Hybrid Larimer 4-...	Estes Valley Recr...	7	1	Estes Valley Recr...	PO Box 1379		Estes Park	CO	80517
2	03059	Arapahoe Public ...	Orchard Hills Met...	7	1	Orchard Hills Met...	1700 Lincoln St S...	c/o Spencer Fane...	Denver	CO	80203
3	03087	Arapahoe Public ...	Arapahoe Park &...	7	1	Arapahoe Park &...	16799 East Lake ...		Centennial	CO	80016
4	30028	DOLA CTF 04-14...	Foothills Park & R...	7	1	Foothills Park & R...	6612 S. Ward Str...		Littleton	CO	80127
5	09005	DOLA CTF 04-14...	Cheyenne Wells ...	7	1	Cheyenne Wells ...	PO Box 9		Cheyenne Wells	CO	80810-0009
6	10004	DOLA CTF 04-14...	Clear Creek Metr...	7	1	Clear Creek Metr...	PO Box 1149		Idaho Springs	CO	80452-1149
7	30016	DOLA CTF 04-14...	Columbine Knolls ...	7	1	Columbine Knolls ...	6191 West Plymo...		Littleton	CO	80128
8	01102	DOLA CTF 04-14...	Bennett Park and...	7	1	Bennett Park An...	P.O. Box 379		Bennett	CO	80102
9	03015	DOLA CTF 04-14...	Cherry Creek Vis...	7	1	Cherry Cr. Vista ...	PO Box 4610		Parker	CO	80134
10	05010	DOLA CTF 04-14...	Springfield Metro...	7	1	Springfield Metro...	PO Box 214		Springfield	CO	81073
11	05018	DOLA CTF 04-14...	Vilas Metropolita...	7	1	Vilas Metropolita...	PO Box 601		Vilas	CO	81087
12	22022	DOLA CTF 04-14...	Penrose Park & R...	7	1	Penrose Park & R...	415 4th Ave		Penrose	CO	81240
13	05022	DOLA CTF 04-14...	Walsh Metropolit...	7	1	Walsh Metropolit...	PO Box 614	500 E. Oak	Walsh	CO	81090
14	05026	DOLA CTF 04-14...	Campo Park & Re...	7	1	Campo Park & Re...	PO Box 59		Campo	CO	81029
15	25005	DOLA CTF 04-14...	Fraser Valley Met...	7	1	Fraser Valley Met...	PO Box 3348		Winter Park	CO	80482
16	25013	DOLA CTF 04-14...	Grand Lake Metr...	7	1	Grand Lake Metr...	PO Box 590		Grand Lake	CO	80447-0590
17	30023	DOLA CTF 04-14...	Evergreen Park ...	7	1	Evergreen Park ...	1521 Bergen Pkwy		Evergreen	CO	80439-7925
18	30057	DOLA CTF 04-14...	Leawood Metrop...	7	1	Leawood Metro. ...	P.O. Box 620802		Littleton	CO	80162
19	46013	DOLA CTF 04-14...	Loghill Village Par...	7	1	Loghill Village Par...	180 Ponderosa Dr		Ridgway	CO	81432
20	62074	DOLA CTF 04-14...	Carbon Valley Pa...	7	1	Carbon Valley Pa...	701 Fifth Street		Frederick	CO	80530
21	62104	DOLA CTF 04-14...	Thompson Rivers...	7	1	Thompson Rivers...	110 South Cente...		Milliken	CO	80543

Fig 1.3 : Attribute table of all the Park Reserves in the state of Colorado

		ftype	mappedscal	secondarys	slipsense_	fault_id	section_id	azimuth	cooperator	length	CFM_URL	FACODE	URL_OLD
1	1	Well constrained	250		1	2386	a	356	Utah Geological S...	24.70102627000	http://geohazard...	12	http://geohazard...
2	1	Well constrained	250		1	919		140	Bureau of Econo...	1.51695245000	http://geohazard...	15	
3	2	Moderately const...	250		1	919		342	Bureau of Econo...	1.79046471000	http://geohazard...	25	
4	1	Well constrained	250		1	992		205	Arizona Geologic...	11.45415261000	http://geohazard...	15	http://geohazard...
5	1	Well constrained	250		1	992		216	Arizona Geologic...	10.20412559000	http://geohazard...	15	http://geohazard...
6	3	Inferred	250		1	919		324	Bureau of Econo...	16.19149775000	http://geohazard...	35	
7	3	Inferred	250		1	919		182	Bureau of Econo...	1.95152140000	http://geohazard...	35	
8	1	Well constrained	250		2	2316		148	Colorado Geologi...	3.41091655000	http://geohazard...	13	http://geohazard...
9	3	Inferred	250		1	622		325	U.S. Geological S...	24.60686071000	http://geohazard...	35	
10	2	Moderately const...	250		1	735		31	GEO-HAZ Consul...	6.89988802000	http://geohazard...	25	http://geohazard...
11	1	Well constrained	250		1	1550		10	Piedmont Geosci...	42.64502675000	http://geohazard...	15	http://geohazard...
12	1	Well constrained	250		1	1610		327	Piedmont Geosci...	28.17098737000	http://geohazard...	15	http://geohazard...
13	1	Well constrained	250		1	1513		351	Piedmont Geosci...	2.55957054000	http://geohazard...	13	http://geohazard...
14	1	Well constrained	250		1	1430		355	Piedmont Geosci...	5.06449759000	http://geohazard...	15	http://geohazard...
15	2	Moderately const...	250		1	1346		23	Piedmont Geosci...	70.04038539000	http://geohazard...	23	http://geohazard...
16	1	Well constrained	250		1	1686		8	Piedmont Geosci...	40.55664695000	http://geohazard...	15	http://geohazard...
17	1	Well constrained	250		1	1006		45	Arizona Geologic...	4.13460463000	http://geohazard...	14	http://geohazard...
18	1	Well constrained	250		3	141	a	194	U.S. Geological S...	1.21741691000	http://geohazard...	12	http://geohazard...
19	2	Moderately const...	250		1	1686		7	Piedmont Geosci...	29.60177234000	http://geohazard...	25	http://geohazard...
20	1	Well constrained	250		1	1635		351	Piedmont Geosci...	7.92348138000	http://geohazard...	15	http://geohazard...
21	2	Moderately const...	250		1	1346		43	Piedmont Geosci...	5.19916426000	http://geohazard...	23	http://geohazard...

Fig 1.4 : Attribute table of all the Faults in the state of Colorado

	LINEARID	FULLNAME	RTTYP	MTFCC
1	1104474838228	I- 70 Business Lp	I	S1200
2	1104474953659	I- 70 Business Lp	I	S1200
3	1104474838225	I- 70 Business Lp	I	S1200
4	1104474953660	I- 70 Business Lp	I	S1200
5	1104977739397	I- 70 Business Lp	I	S1200
6	1104474838227	I- 70 Business Lp	I	S1200
7	1104474838226	I- 70 Business Lp	I	S1200
8	1104977739398	I- 70 Business Lp	I	S1200
9	1104259080442	N Hwy 50 Busine...	M	S1200
10	1104474984061	State Hwy 13 Byp	S	S1200
11	1104472830261	Wadsworth Byp	M	S1200
12	1104474984060	State Hwy 13 Byp	S	S1200
13	1104472827712	Wadsworth Byp	M	S1200
14	1104472827759	Wadsworth Byp	M	S1200
15	1104474984059	State Hwy 13 Byp	S	S1200
16	1104469767419	US Hwy 34 Byp	U	S1200
17	110755376188	I- 70 Bus	I	S1200
18	1104259114336	I- 70 Bus	I	S1200
19	1104259508972	I- 70 Bus	I	S1200
20	1104742588567	I- 70 Bus	I	S1200
21	1104742588575	I- 70 Bus	I	S1200
22	110454604994	US Hwy 385 Bus	U	S1200

Fig 1.5 : Attribute table of all the Major Roads in the state of Colorado

	UACE10	AFFGEOID10	GEOID10	NAME10	LSAD10	UATYP10	ALAND10	AWATER10
1	04087	400C100US04087	04087	Auburn, NE	76	C	5204595	0
2	86653	400C100US86653	86653	Taos, NM	76	C	41537873	0
3	70156	400C100US70156	70156	Plattsburgh, NY	76	C	67103610	948468
4	35515	400C100US35515	35515	Greenwich, NY	76	C	4536217	35372
5	41779	400C100US41779	41779	Irrigon, OR	76	C	4457305	0
6	87058	400C100US87058	87058	Temple, TX	75	U	140175267	500208
7	41644	400C100US41644	41644	Iowa Park, TX	76	C	7556077	187040
8	11755	400C100US11755	11755	Burlington, VT	75	U	159958092	2716845
9	74746	400C100US74746	74746	Richmond, VA	75	U	1275291571	22275832
10	15076	400C100US15076	15076	Centralia, WA	76	C	81796394	746235
11	17524	400C100US17524	17524	Clearwood, WA	76	C	3409084	829947
12	50986	400C100US50986	50986	Logan, WV	76	C	20845400	963872
13	03034	400C100US03034	03034	Arecibo, PR	75	U	217723163	1595322
14	55063	400C100US55063	55063	Marshall, WI	76	C	3640009	187143
15	98020	400C100US98020	98020	Yuma, AZ--CA	75	U	152431440	483414
16	62407	400C100US62407	62407	New Haven, CT	75	U	792593469	15833342
17	67134	400C100US67134	67134	Palm Coast--Day...	75	U	463874984	29662605
18	16885	400C100US16885	16885	Cincinnati, OH--K...	75	U	2040246270	24610635
19	96697	400C100US96697	96697	Winter Haven, FL	75	U	347914570	80368989
20	40321	400C100US40321	40321	Houghton Lake, MI	76	C	23060340	854071
21	29089	400C100US29089	29089	Fargo, ND--MN	75	U	181901122	131153
22	48043	400C100US48043	48043	Laurel, MS	76	C	50402225	89204

Fig 1.6 : Attribute table of all the Urban Areas

This data was projected onto the map using Quantum GIS. The map looked as following for each of the attribute table.

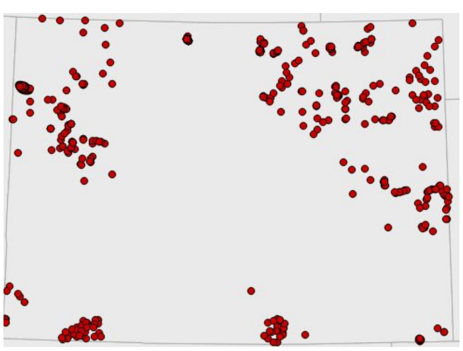
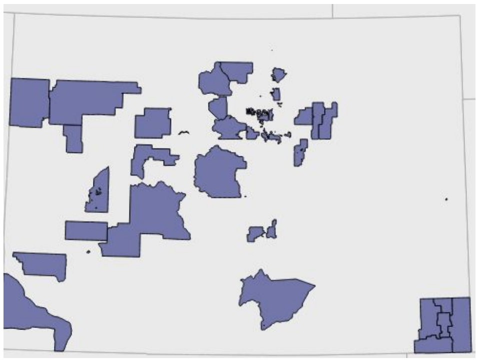


Fig 2.1 : All well sites in the state of Colorado

Fig 2.2 : All Water Conservation in the state of Colorado



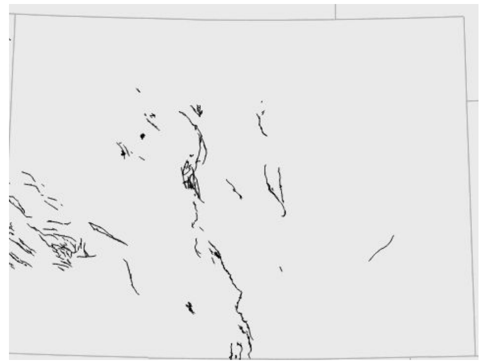
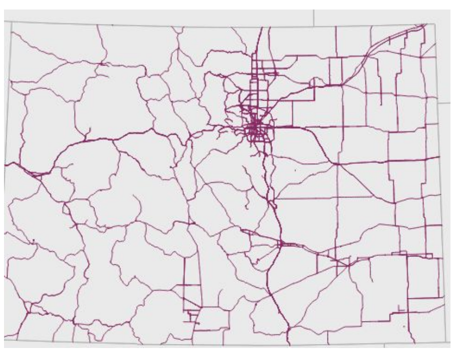


Fig 2.3 : All Park Areas in the state of Colorado

Fig 2.4: All Fault Areas in the state of Colorado



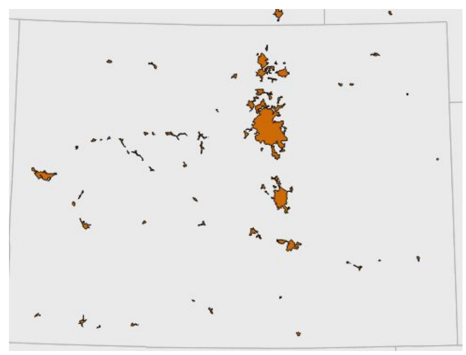


Fig 2.5: All Major Roads in the state of Colorado

Fig 2.5: All Urban Cities in the state of Colorado

Data Setup

Once all the data has been loaded into QGIS it is necessary to set them to same Coordinate Reference System (CRS). A spatial reference system (SRS) or coordinate reference system (CRS) is a coordinate-based local, regional or global system used to locate geographical entities. A spatial reference system defines a specific map projection, as well as transformations between different spatial reference systems. It is necessary to set them all to the same CRS because while using spatial algorithms like differencing different CRS can lead to incorrect Results.

We set them all to the same CRS of World Aizmuthal Distance, one of the most commonly used CRS for spatial Analysis. To set the CRS the following steps can be followed.

1. Right Click on the layer whose CRS has to be set
2. Click on Set Layer CRS
3. Select World Aizmuthal Distance from the pop up box below

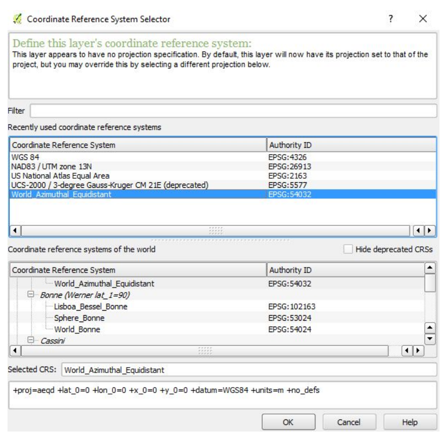


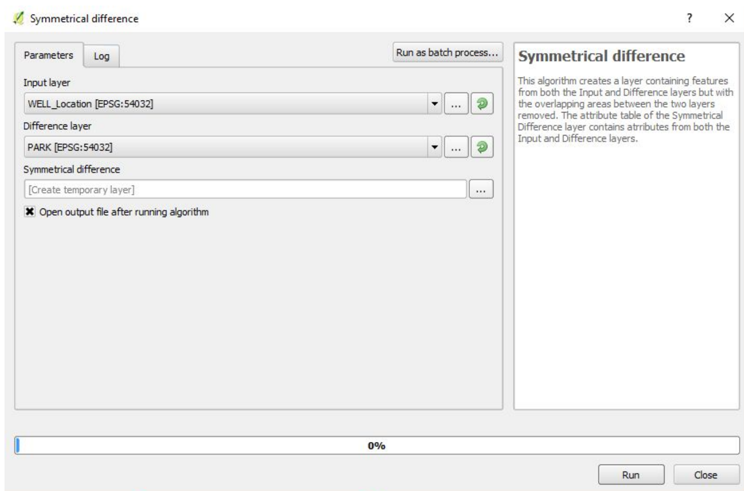
Fig 3.1 : Coordinate Reference System Selector

Data Analysis

Once the CRS is set we can move ahead and start applying the spatial analysis. For the Park and Water Conservation areas we use the differencing algorithm to remove the sites which are within their boundaries.

For Differencing Algorithm :

- Go to Vector > GeoProcessing tools > Symmetrical Differencing



- Select the Input area as the well location and the Difference layer as the Park layer. In the input box below select save to file. Click on Run.

The output is as following:

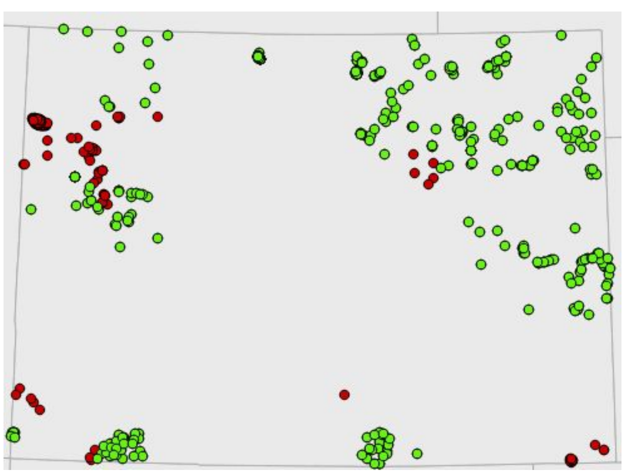


Fig 3.2 : The wells left after Differencing are in Green

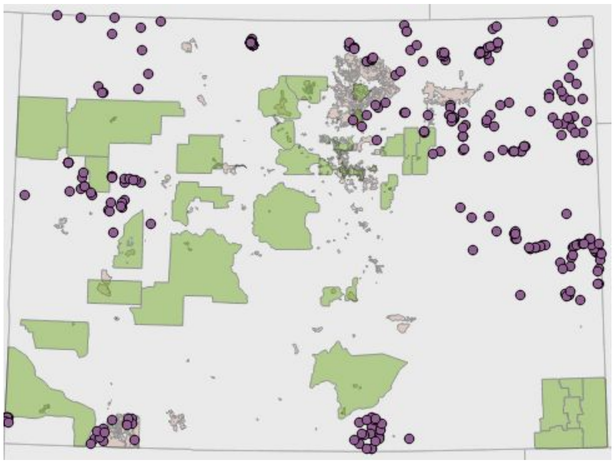


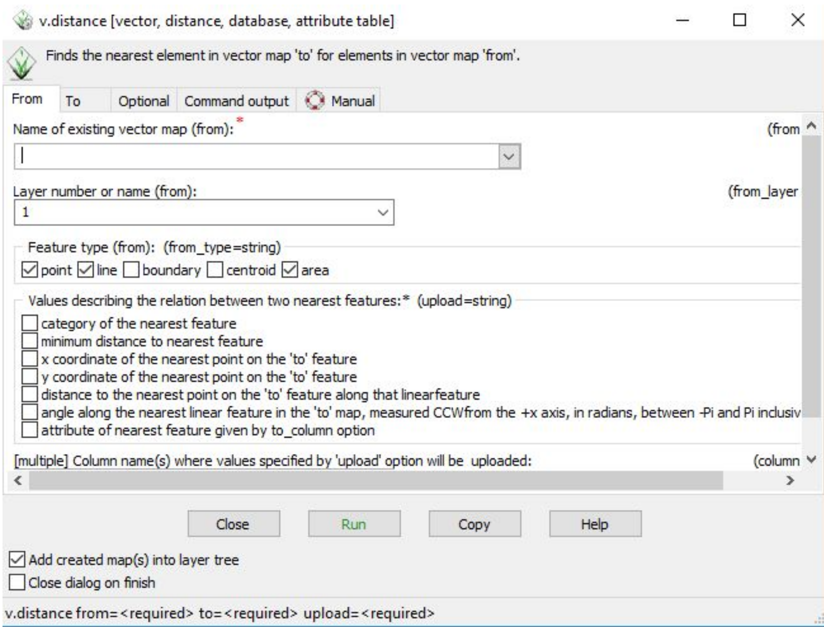
Fig 3.3 : After Differencing with Park and Water Conservation Areas

This helped us to come down to 299 filtered fracking sites which were not in Park and Conservation areas. After this we went to filter locations away from Earthquake faults. For this we use the Distance Algorithm which is based on the Nearest neighbor analysis. The algorithm tries to find the nearest neighbor from the start point and the shortest distance between the two.

To find the distances we use GRASS GIS:

- Select Vector > Nearest Element
- In From field select the layer which has been created in the above steps
- In the To field select the Faults layer
- Select feature as point for From field and line feature for To field
- Select value as distance
- Put in the column name where the distance value has to stored

- Run the Algorithm



After calculating the distances from all the three features of Faults, Highways and Urban Areas we get the following.

utm_x	utm_y	LocQual	field_name	name	api_seq_nu	api_county	LocationID	LGID	SOURCE	url_2
573910	4423921	ACTUAL LatLong	NILE	FOUNDATION EN...	06084	001	319646	12351.79942370...	40904.46010558...	88126.42864749...
573903	4423174	ACTUAL LatLong	NILE	FOUNDATION EN...	06115	001	319649	13098.80435594...	41493.79244971...	88085.60659334...
574307	4424358	ACTUAL LatLong	NILE	FOUNDATION EN...	06133	001	319650	11921.49287303...	40314.94786921...	88545.69357754...
582838	4400716	ACTUAL LatLong	LONE TREE	TYLER ROCKIES ...	06908	001	319830	1367.27203889309	55755.862732101	95200.56397387...
728354	4305125	ACTUAL LatLong	CHEYENNE WELLS	MULL DRILLING ...	06461	017	321615	1432.971037048...	48321.76787230...	88063.26993917...
755469	4291806	ACTUAL LatLong	FRONTERA	CITATION OIL & ...	06778	017	321718	12804.14641134...	64450.99285034...	106322.9832934...
744550	4314027	ACTUAL LatLong	HARKER RANCH	MID-CON ENERG...	07046	017	321820	10045.16169193...	40085.35264355...	106473.31048565
745069	4313987	ACTUAL LatLong	HARKER RANCH	MID-CON ENERG...	07078	017	321830	10093.512750928	40246.92390438...	106886.0404497...
611125	4345259	ACTUAL LatLong	RUBICON	CHURCHILL ENE...	06159	073	309598	1398.5507145161	81605.64755635...	99903.60237987...
640661	4497331	ACTUAL LatLong	SHIELD	GRAYHORSE OP...	05562	075	312139	1007.56271740631	3100.036036710...	170258.7156142...
143358	4129297	Planned Footage	CACHE	MONUMENT GLO...	05353	083	313445	10457.1179772997	37626.41919479...	85058.11686687...
677434	4408701	ACTUAL LatLong	SPOTTED DOG	DAVIS, LLC* ED...	07551	121	317055	13502.42658539...	37527.2966466307	154544.3364765...
683560	4445311	ACTUAL LatLong	HIGH POCKETS	PETRON DEVELO...	09376	121	317152	1109.693226212...	9155.434245649...	191655.1269799...
593110	4505287	ACTUAL LatLong	LILLI	NOBLE ENERGY I...	13900	123	326943	10334.08585008...	46886.12812814...	131988.7943752...
677804	4408691	ACTUAL LatLong	SPOTTED DOG	DAVIS, LLC* ED...	10634	121	317342	13640.26467325...	37378.41320895...	154587.428906888
677143	4408803	ACTUAL LatLong	SPOTTED DOG	DAVIS, LLC* ED...	10690	121	317363	13487.3811561932	37561.89754832...	154604.2666214...
565941	4513445	ACTUAL LatLong	KEOTA	DIAMOND OPER...	22125	123	332312	14373.26343809...	47425.99171071...	116095.4239289...
711328	4472064	ACTUAL LatLong	WILDCAT	AUGUSTUS ENER...	08884	125	304698	10136.73500578...	31442.93511394...	223424.59797983

Fig 3.3 : Distance Calculation

After filtering for Farthest distance from Faults and Urban Cities and Proximity to Highways we are left with 18 of the best sites for Fracking.

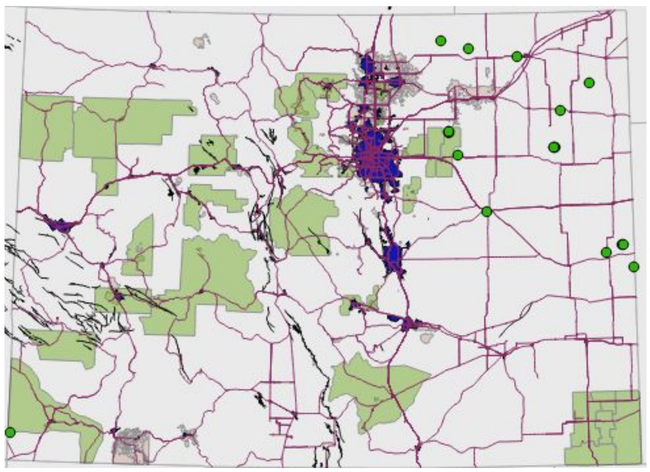


Fig 3.18 Map of the 18 Filtered Fracking locations

Once we had the fracking location we had to prioritize them. For this we also took into consideration the Media Reactions which was in the city/area of the site.

Sentiment Analysis

We created a Python tool using Selenium and Beautifulsoup to create an automation tool that scrapes the main headlines of data in the particular area of the above 18 filtered website.

Once we have obtained the articles we used AFIN-111 tools to get a sentiment score for the media reactions.

These media reactions are then used to calculate priority scores using the AHP model.

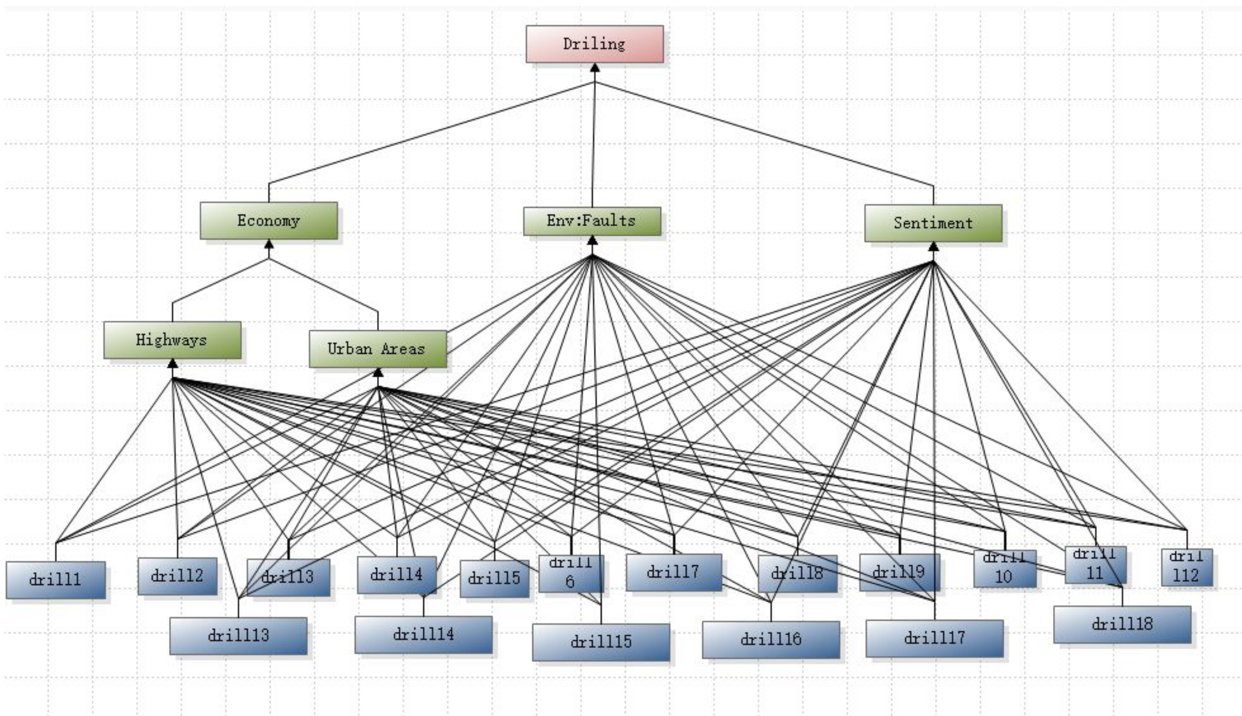
```
In [92]: import os
         from selenium import webdriver
         import urllib.request
         from bs4 import BeautifulSoup as bs


         for x in z:
               #  try:
                 print(x)
                 chromedriver = "/Users/abhinavchandel/Desktop/chromedriver"
                 os.environ["webdriver.chrome.driver"] = chromedriver
                 driver = webdriver.Chrome(chromedriver)
                 driver.get("http://bing.com")

                 element = driver.find_element_by_id("sb_form_q")

                 element.send_keys(x)

                 driver.find_element_by_id("sb_form_go").click()

                 driver.find_element_by_link_text("News").click()

             #driver.implicitly_wait(5000)

                 url=driver.current_url

                 request = urllib.request.Request(url)
                 response = urllib.request.urlopen(request)
                 data = response.read()
                 response.close()

                 soup = bs(data)

                 par.extend(soup.findAll("a", { "class" : "title" }))
                 print(len(par))
                 for x in range(0,len(par)):
                     print(par[x].get_text())
```

The above python script uses selenium to go to the bing news section by sending the key “Area” Oil Wells. All the news headlines are then scraped and a list of headlines is created for that particular area. These headlines are then put into an online AFIN-111 sentiment analysis tool to get a net sentiment score which is used to create a 18*18 matrix for AHP analysis.

AHP analysis

The AHP model is a way of selecting alternatives by using Mathematics and Judgement. It uses pairwise comparisons to prioritize Alternatives and Criteria. The AHP model includes a Goal which needs to be fulfilled based on certain criteria and sub criteria. Based on some number of criteria we can select Alternatives and create a Priority vector.

The below diagram shows the Initial structure of the model:



The Goal here is to select optimum drilling/fracking locations. The Criteria on which it is based are broadly classified as Economic, Environmental and Sentiments. There are two sub criteria for Economy – Highways and Urban Areas. The final layer consist of the 18 filtered Alternatives.

Based on the judgements and knowledge obtained during our Secondary Research, we provided the following scores to the matrix below:

	Economy	Env:Faults	Sentiment
Economy		1/7	1/4
Env:Faults			4
Sentiment			

This means Environment are 7 times more important than Economy and Sentiments are 4 times more important than Economy and Environment is 4 times more important than Sentiments.

2. Highways 一致性比例: 0.0991; 对"Driling"的权重: 0.5714; λmax: 20.7183

Highways	drill1	drill2	drill6	drill10	drill11	drill12	drill13	drill9	drill3	drill4	drill5	drill7	drill8	drill18	drill17	drill16	drill15	drill14	Wi
drill1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0483
drill2	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0483
drill6	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0483
drill10	1.0000	1.0000	1.0000	1.0000	1.0000	7.0000	1.0000	1.0000	1.0000	1.0000	1.0000	7.0000	3.0000	7.0000	9.0000	9.0000	9.0000	8.0000	0.1199
drill11	1.0000	1.0000	1.0000	1.0000	1.0000	7.0000	1.0000	1.0000	1.0000	1.0000	1.0000	7.0000	3.0000	7.0000	9.0000	9.0000	9.0000	7.0000	0.1186
drill12	1.0000	1.0000	1.0000	0.1429	0.1429	1.0000	1.0000	1.0000	0.3418	0.3484	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0317
drill13	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0483
drill9	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0483
drill3	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	7.0000	1.0000	7.0000	9.0000	9.0000	9.0000	7.0000	0.1030
drill4	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	7.0000	1.0000	9.0000	9.0000	9.0000	9.0000	9.0000	0.1082
drill5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0483
drill7	1.0000	1.0000	1.0000	0.1429	0.1429	1.0000	1.0000	1.0000	0.1429	0.1429	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0297
drill8	1.0000	1.0000	1.0000	0.3333	0.3333	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	5.0000	5.0000	5.0000	5.0000	5.0000	0.0663
drill18	1.0000	1.0000	1.0000	0.1429	0.1429	1.0000	1.0000	1.0000	0.1429	0.1111	1.0000	1.0000	0.2000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0269
drill17	1.0000	1.0000	1.0000	0.1111	0.1111	1.0000	1.0000	1.0000	0.1111	0.1111	1.0000	1.0000	0.2000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0264
drill16	1.0000	1.0000	1.0000	0.1111	0.1111	1.0000	1.0000	1.0000	0.1111	0.1111	1.0000	1.0000	0.2000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0264
drill15	1.0000	1.0000	1.0000	0.1111	0.1111	1.0000	1.0000	1.0000	0.1111	0.1111	1.0000	1.0000	0.2000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0264
drill14	1.0000	1.0000	1.0000	0.1250	0.1429	1.0000	1.0000	1.0000	0.1429	0.1111	1.0000	1.0000	0.2000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0268

Highways : Closer the better

To do a pairwise comparisons for the Highway criteria we took ratios of each distance value with every other value. So if Drill site ‘X’ is ‘Z’ times away from Drill site ‘Y’ then Drill site ’Y’ is ‘Z’ times more important then Drill site ‘X’.

3. Urban Areas 一致性比例: 0.0875; 对"Driling"的权重: 0.2857; λmax: 20.3998

Urban Areas	drill1	drill2	drill6	drill10	drill11	drill12	drill13	drill9	drill3	drill4	drill5	drill7	drill8	drill18	drill17	drill16	drill15	drill14	Wi
drill1	1.0000	1.0000	2.0000	1.0000	1.0000	1.0000	1.0000	2.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0535
drill2	1.0000	1.0000	2.0000	1.0000	1.0000	1.0000	1.0000	2.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0535
drill6	0.5000	0.5000	1.0000	1.0000	1.0000	1.0000	1.0000	2.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0485
drill10	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0490
drill11	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	2.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0511
drill12	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0490
drill13	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	2.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0511
drill9	0.5000	0.5000	0.5000	1.0000	0.5000	1.0000	0.5000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0427
drill3	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	9.0000	9.0000	1.0000	1.0000	0.0829
drill4	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	9.0000	9.0000	9.0000	1.0000	1.0000	9.0000	9.0000	0.1432
drill5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0490
drill7	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1111	1.0000	1.0000	1.0000	1.0000	5.0000	4.0000	1.0000	1.0000	0.0576
drill8	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1111	1.0000	1.0000	1.0000	3.0000	1.0000	1.0000	4.0000	5.0000	0.0607
drill18	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1111	1.0000	1.0000	0.3333	1.0000	1.0000	1.0000	1.0000	1.0000	0.0408
drill17	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1111	1.0000	1.0000	0.2000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0431
drill16	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1111	1.0000	1.0000	0.2500	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0433
drill15	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1111	1.0000	1.0000	0.2500	1.0000	1.0000	1.0000	1.0000	1.0000	0.0406
drill14	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.1111	1.0000	1.0000	0.2000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0404

Urban Areas : Farther the better

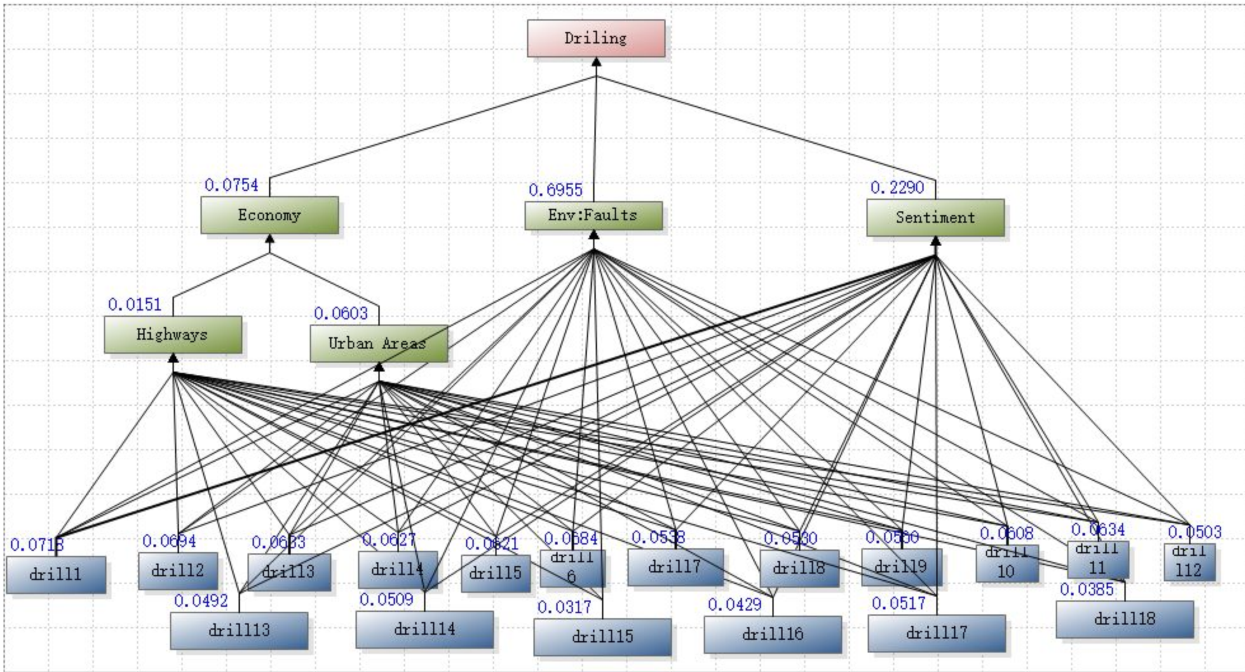
If Drill site ‘X’ is ‘Z’ times away from Drill site ‘Y’ then Drill site ’X’ is ‘Z’ times more important then Drill site ‘Y’.

4. Faults 一致性比例: 0.0189; 对"Driling"的权重: 0.1429; λmax: 18.5150

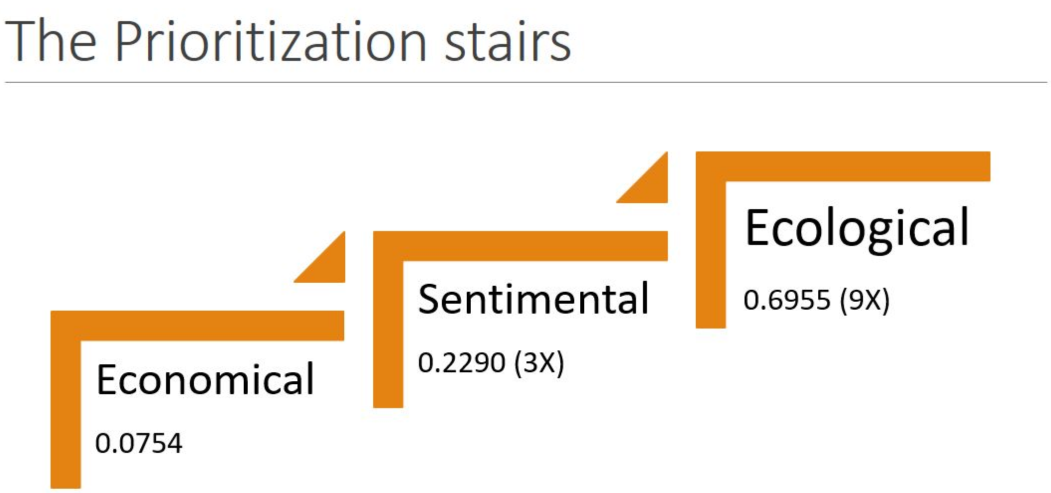
Faults	drill1	drill2	drill6	drill10	drill11	drill12	drill13	drill9	drill3	drill4	drill5	drill7	drill8	drill18	drill17	drill16	drill15	drill14	Wi
drill1	1.0000	1.0000	1.0000	2.0000	1.0000	2.0000	2.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	3.0000	1.0000	2.0000	2.0000	1.0000	0.0705
drill2	1.0000	1.0000	1.0000	2.0000	1.0000	2.0000	2.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	3.0000	1.0000	2.0000	2.0000	1.0000	0.0705
drill6	1.0000	1.0000	1.0000	2.0000	1.0000	2.0000	2.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	3.0000	1.0000	2.0000	2.0000	1.0000	0.0705
drill10	0.5000	0.5000	0.5000	1.0000	1.0000	2.0000	2.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	2.0000	1.0000	2.0000	2.0000	1.0000	0.0597
drill11	1.0000	1.0000	1.0000	1.0000	1.0000	2.0000	2.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	3.0000	1.0000	2.0000	2.0000	1.0000	0.0673
drill12	0.5000	0.5000	0.5000	0.5000	0.5000	1.0000	2.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	2.0000	1.0000	1.0000	1.0000	1.0000	0.0492
drill13	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	2.0000	1.0000	1.0000	1.0000	1.0000	0.0454
drill9	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	N/A	1.0000	2.0000	1.0000	1.0000	1.0000	1.0000	0.0560
drill3	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	2.0000	1.0000	2.0000	2.0000	1.0000	0.0603
drill4	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0540
drill5	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	3.0000	1.0000	2.0000	2.0000	2.0000	0.0650
drill7	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	N/A	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0539
drill8	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0540
drill18	0.3333	0.3333	0.3333	0.5000	0.3333	0.5000	0.5000	0.5000	0.5000	1.0000	0.3333	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0343
drill17	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0540
drill16	0.5000	0.5000	0.5000	0.5000	0.5000	1.0000	1.0000	1.0000	0.5000	1.0000	0.5000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0415
drill15	0.5000	0.5000	0.5000	0.5000	0.5000	1.0000	1.0000	1.0000	0.5000	1.0000	0.5000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0415
drill14	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.5000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.0523

Faults : Farther the better

If Drill site ‘X’ is ‘Z’ times away from Drill site ‘Y’ then Drill site ’X’ is ‘Z’ times more important then Drill site ‘Y’.

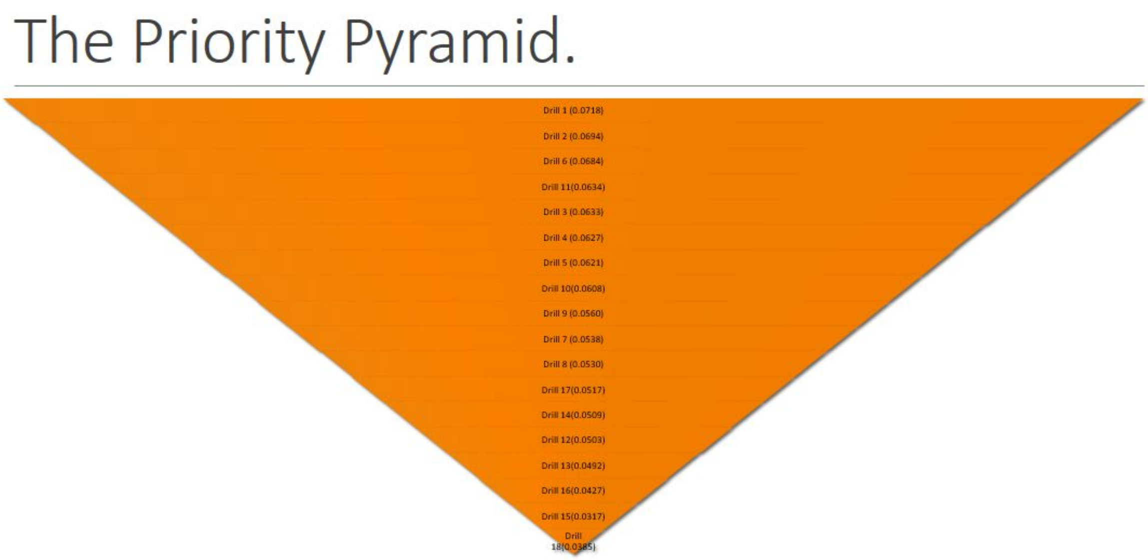


After running the algorithm we get the following weights.



So Ecological factors are 9x more important than Economical and Sentimental are 3x more important than Economic factors.

The final priority vector looks is shown below:



The above priorities for each of the alternative are created by pairwise comparisons of each of the alternatives based on the defined criterion.

Conclusion

After a thorough and all scale analysis of the issue we have created a flexible tool with a strong potential for future applications. While working on this project we had to solve several issues such as:

- **Data conversion.** Numerical data had to be transformed into the form of shapefiles in order to face the requirements of our geospatial software tools.
- **Prioritization of factors.** Details that influence decision making for choosing of a drilling location had to be determined to formulate the framework of our model.
- **Data collection.** The data we used came for various sources and was initially unstructured and messy.

The resulted model has several advantages for entities within the field:

- **Flexibility in regards to changing objectives.** Based on the client's focus in either PR/ ESR/Cost and so on, the alternatives can change. Thereby, the selection of the Geospatial data and also the priority vector will assign different weights to the factors depending on the goals of the company.
- **Zero cost of visual deployment.** No need of expensive geospatial visualization software as the output is delivered in the form of KML files and can be presented in Google Earth or in the form of heat maps/locations on QGIS.

- **Removed dreadlock by weighted mathematical factors**. Similar placed wells can be separated by priority vectors backed by data. Often location can be extremely close to each other and it becomes difficult to select one of the two just by normal qualitative inspection. Because of the weights, assigned by the model, small changes such as distances can have larger impacts in the priority value.
- **Reduction of time in collecting quantitative data.** A lot of time is spent on collecting structured quantitative data, which can be reduced as our model takes qualitative data and converts them into quantitative data. These qualitative data is easily available on state and federal level open data sources.
- **PR team can focus on the lower weighted factors.** Sustained fracking activity attracts negative attention from all corners and it is impossible to track and solve all of them. The prioritized vector tells us which factors are giving least importance and the team can move bottom – up on lookout of such negative attention.
- **Precautions against negative public sentiment.** We are also aware of the sentiments in the area where drilling needs to be done, which can help the client take precautionary steps to protect its public image.

Although we only covered only one state in our work, the model's flexibility allows it to work with the data from any region within the country -

and beyond. As it can process geospatial data from around the planet, the deliverables will change accordingly. A larger scale model that will be able to analyze data on a national or even global level will be based upon similar principles - conversion of qualitative data into quantitative form, creation of shape files and building of an AHP flow. Resulting priority vector will keep the same structure as the one presented in our work, except for its scale. Similarly, more inside information can be analyzed to determine new factors and assign weights to them which, in return, will make the model more precise and hence more attractive for the potential clients.

Overall, this work demonstrates the plethora of tools that can and should be used for better decision making within the fracking industry.

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