Marcellus Shale Drilling

Decision Model for State of Pennsylvania

Christopher Gill, B. Alex Huber, Joshua Shaffer

Marcellus Shale-Overview

The Marcellus Shale formation is the largest unconventional natural gas reserve in the world, containing at least 489 trillion cubic feet of recoverable reserves. The Marcellus Shale formation is located throughout the Allegheny Plateau region of the northern Appalachian region of the United States. This includes southern New York, eastern Ohio, most of West Virginia and northern and western Pennsylvania. According to geology.com, the Marcellus Shale formation lies 5,000'-9,000' below the surface of 60% of the land mass of Pennsylvania. The amount of drilling in the state of Pennsylvania has increased rapidly in the past few years. Economic output in Pennsylvania related to Marcellus Shale drilling increased from $2.3 billion in 2008 to $3.8 billion in 2009. State tax revenues related to drilling increased from $240 million in 2008 to $400 million in 2009. The increase in drilling volume can be attributed to depletion of conventional natural gas reserves. Another reason is the fact that natural gas produces fewer greenhouse gas emissions than coal. An economy-wide shift to lower greenhouse gas emissions thus makes natural gas more attractive.

The Impact

The increase in drilling has brought a few major environmental concerns to the forefront. To capture natural gas, underground shale formations are fractured by injecting a complex mix of fluids and chemicals under high pressure. This process is commonly referred to as "fracking". One major risk associated with fracking is the potential for drinking water contamination caused by the fluids and chemicals used. In addition there is some concern that toxic air emissions near gas wells could occur. There are also concerns regarding wildlife habitats, hazards from trucking operations, damage to roads, and complications with handling of waste water produced by the fracking process. Some communities have also expressed concern for explosions of wells or gas lines in residential areas or near schools. However, many professionals in the natural gas industry believe that few of these fears are realistic based on experience.

In addition to the impacts imparted on the environment, there is potential for economic growth. Drilling could open opportunities of employment in local communities. The employment increase will generate local revenues from spending within these communities. The added jobs will contribute to Pennsylvania's taxable incomes.

A similar endeavor in Texas has left local communities in a prosperous state. The Barnett Shale formation has been tapped there, however, their situation varies from that of Pennsylvania's. In Texas, shale drilling has been a great source of local revenue from taxes. These have contributed to a higher quality of life to the affected

communities by benefiting school districts, county governments, and municipal governments. However, Pennsylvania is currently unable to generate local tax revenues since natural gas is not subject to local taxation. Pennsylvania is the only state in the US with mineral wealth that does not impose a severance tax to compensate residents for the removal of nonrenewable resources. The impact of imposing such a tax is currently being debated in Pennsylvania. Those not in favor of such a tax fear that it would discourage drilling, since the cost of the tax would be difficult to pass on to consumers. The 14 states with greater natural gas production than Pennsylvania all have severance taxes and have experienced drilling growth of 5.2% per year on average.

From the aforementioned, our strategic criteria was selected and encompasses *Economic, Environmental*, and *Social* aspects.

The Objective

Through the Complex Analytical Network Process, we hope to arrive at a conclusion for the state of Pennsylvania concerning the Marcellus Shale formation. In this type of analysis we use Benefits, Opportunities, Costs and Risks for to evaluate each salutation (or alternative).

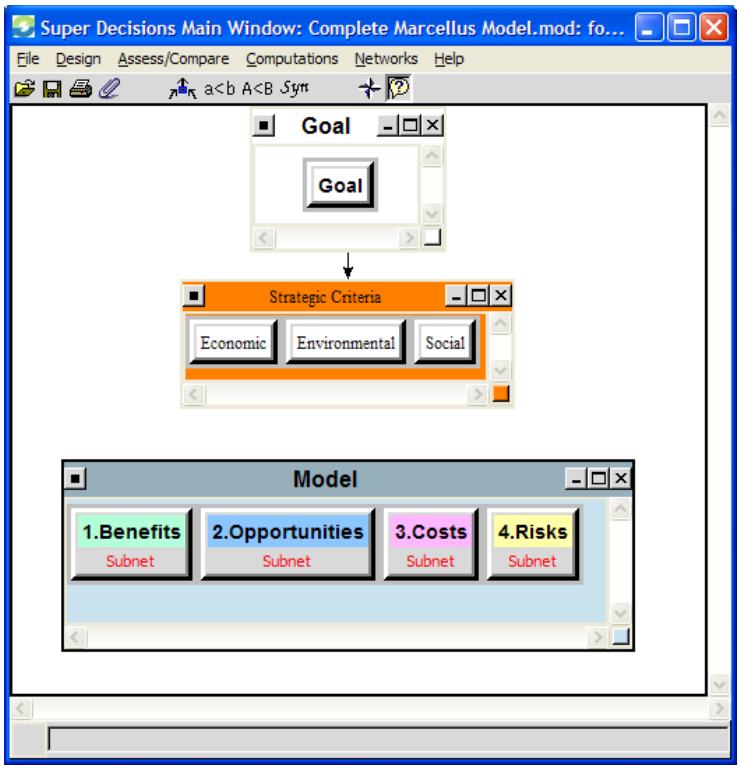


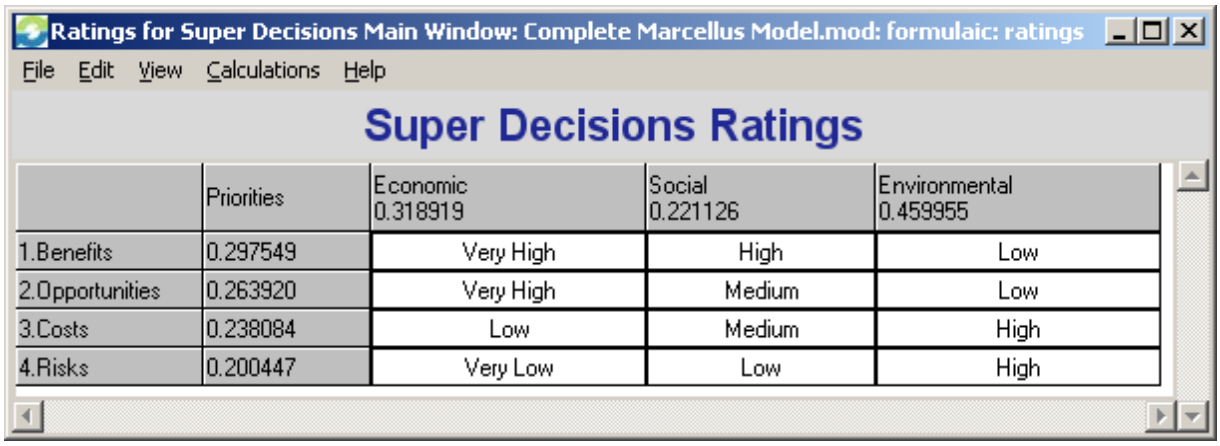
Figure 01: Complex ANP Overview

Three options have been selected as suitable alternatives. In this case, the alternatives present themselves as:

- No Drilling – no large scale increase in drilling currently occurring in PA
- Drilling with regulation but without taxation
- Drilling with regulation and taxation – includes imposing a new severance tax comparable to those used in other states with mineral wealth

Where regulation is referred to as the policies protecting social rights and the environment. It is clear that the extent to which these policies will apply have significant impacts on local communities and drilling industry. The ideal solution would enable companies to drill with limited environmental risk imparted on the community.

The BOCR nodes help us to produce the most valuable outcome. However, we cannot say that the BOCR merits are weighted equally. For instance, it is in our interest to protect the environment while remaining financially stable. We first decided to analyze the decision from the perspective of the state. To distribute the perceived values, a ratings model has been applied to appropriately determine the magnitude of each merits' influence in the decision. We categorize the value of each BOCR merit for the corresponding three control criteria. The ratings selected for the synthesis are depicted below.



	Priorities	Economic 0.318919	Social 0.221126	Environmental 0.459955
1.Benefits	0.297549	Very High	High	Low
2.Opportunities	0.263920	Very High	Medium	Low
3.Costs	0.238084	Low	Medium	High
4.Risks	0.200447	Very Low	Low	High

Figure 02: ANP Synthesis Ratings

The Network

The model integrates a complex structure of decision criteria and pair wise comparisons. For the first subnet of each BOCR merit node, we have chosen "Environmental", "Economic", and "Sociopolitical" to describe groups of our control criteria. See the figure below for a representation of the primary subnet for Benefits node.

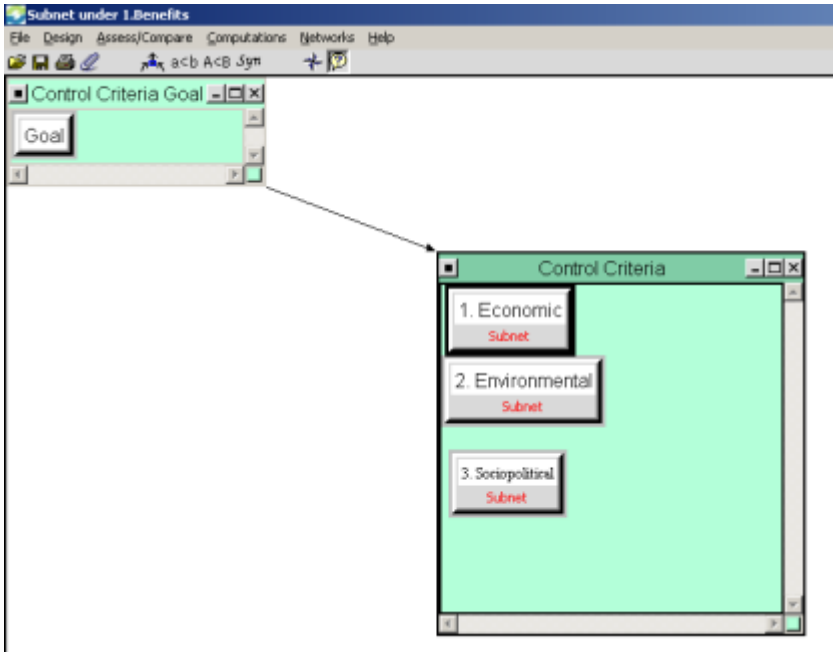
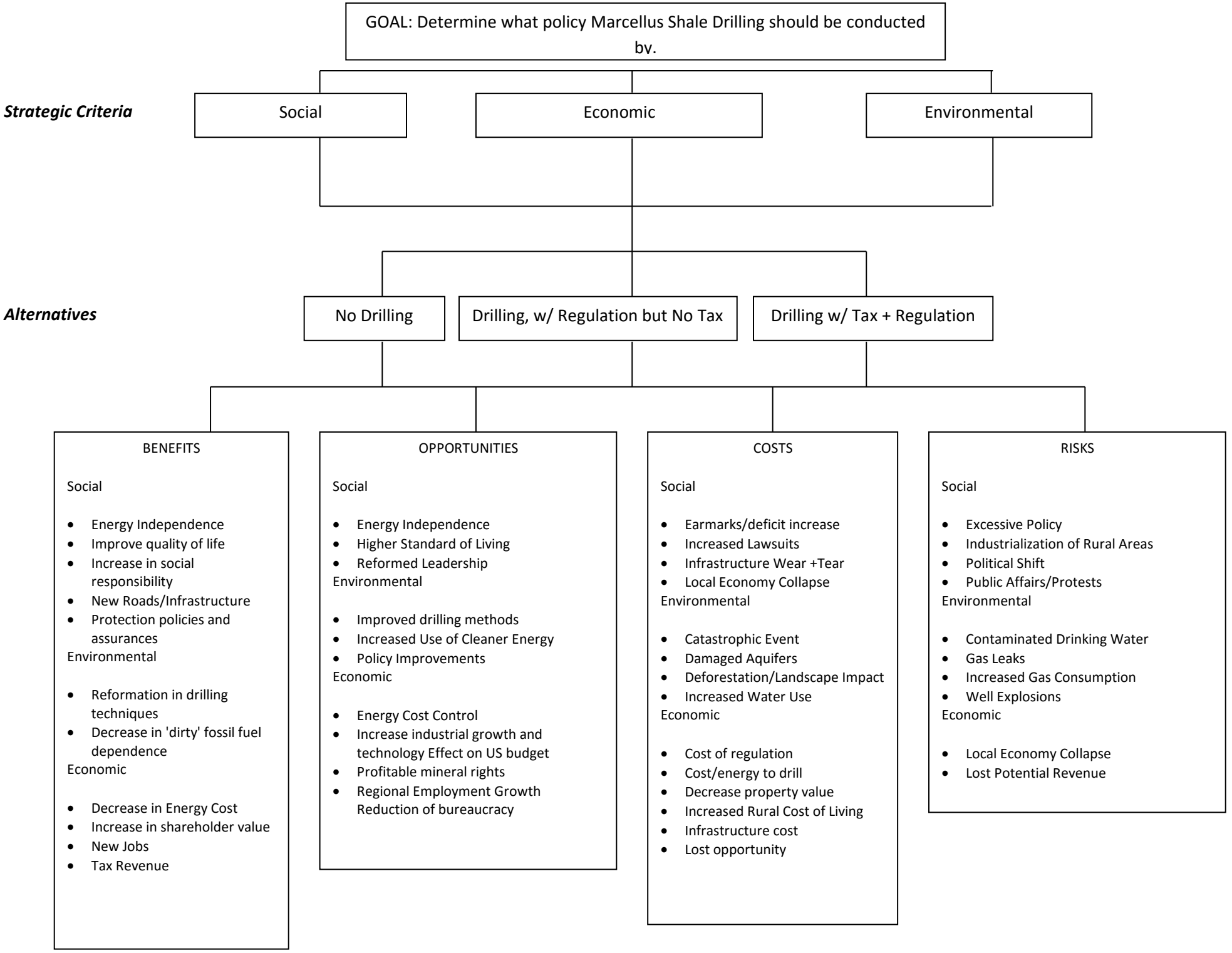


Figure 03: Example view of subnet structure

Within these groups, we have constructed networks to prioritize the value of each alternative. The full network summary to the third level is given in the following table. The table depicts the priorities associated with each criteria. Additionally, a "Global Priorities" field denotes the relative influence on the model prior to the influence of "Ratings" or "Sensitivity."

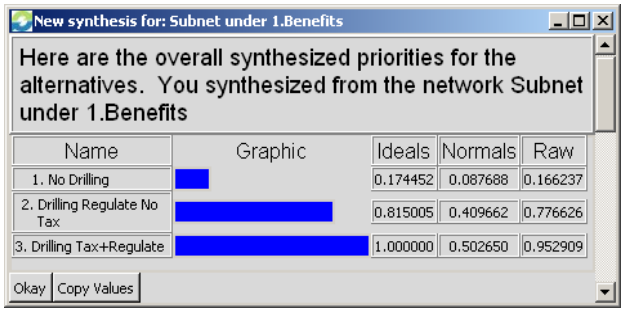

GOAL: Determine what policy Marcellus Shale Drilling should be conducted by.
Strategic Criteria
Social
Economic
Environmental
Alternatives
No Drilling
Drilling, w/ Regulation but No Tax
Drilling w/ Tax + Regulation
BENEFITS
Social
Energy Independence
Improve quality of life
Increase in social responsibility
New Roads/Infrastructure
Protection policies and assurances
Environmental
Reformation in drilling techniques
Decrease in 'dirty' fossil fuel dependence
Economic
Decrease in Energy Cost
Increase in shareholder value
New Jobs
Tax Revenue
OPPORTUNITIES
Social
Energy Independence
Higher Standard of Living
Reformed Leadership
Environmental
Improved drilling methods
Increased Use of Cleaner Energy
Policy Improvements
Economic
Energy Cost Control
Increase industrial growth and technology Effect on US budget
Profitable mineral rights
Regional Employment Growth
Reduction of bureaucracy
COSTS
Social
Earmarks/deficit increase
Increased Lawsuits
Infrastructure Wear +Tear
Local Economy Collapse
Environmental
Catastrophic Event
Damaged Aquifers
Deforestation/Landscape Impact
Increased Water Use
Economic
Cost of regulation
Cost/energy to drill
Decrease property value
Increased Rural Cost of Living
Infrastructure cost
Lost opportunity
RISKS
Social
Excessive Policy
Industrialization of Rural Areas
Political Shift
Public Affairs/Protests
Environmental
Contaminated Drinking Water
Gas Leaks
Increased Gas Consumption
Well Explosions
Economic
Local Economy Collapse
Lost Potential Revenue

BOCR	Control Criteria	Clusters	Elements	Priorities	Global Priorities
Benefits	Economic	Financial	Decrease in Energy Cost	0.1659	0.0138
			Increase in shareholder value	0.1047	0.0087
			New Jobs	0.3108	0.0259
			Tax Revenue	0.4186	0.0349
	Environmental	Environmental Benefits	Reformation in drilling techniques	0.3505	0.0292
			Decrease in 'dirty' fossile fuel dependence	0.6495	0.0541
	Sociopolitical	Social Benefits	Energy Independence	0.0517	0.0043
			Improve quality of life	0.2312	0.0193
			Increase in social responsibility	0.1677	0.0140
			New Roads/Infrastructure	0.3304	0.0275
			Protection policies and assurances	0.2190	0.0183
Opportunities	Economic	Economic Opportunities	Energy Cost Control	0.0807	0.0067
			Increase industrial growth and technology	0.4463	0.0372
			Profitable mineral rights	0.1245	0.0104
			Regional Employment Growth	0.3485	0.0290
	Environmental	Environmental Opportunities	Improved drilling methods	0.3317	0.0276
			Increased Use of Cleaner Energy	0.4237	0.0353
			Policy Improvements	0.2446	0.0204
	Sociopolitical	Social Opportunities	Energy Independence	0.1484	0.0124
			Higher Standard of Living	0.6084	0.0507
			Reformed Leadership	0.2433	0.0203
Costs	Economic	Economic Costs	Cost of regulation	0.0991	0.0083
			Cost/energy to drill	0.0545	0.0045
			Decrease property value	0.1534	0.0128
			Increased Rural Cost of Living	0.1206	0.0101
			Infrastructure cost	0.3324	0.0277
			Lost opportunity	0.2400	0.0200
	Environmental	Environmental Costs	Catastrophic Event	0.1120	0.0093
			Damaged Aquifers	0.4816	0.0401
			Deforestation/Landscape Impact	0.1925	0.0160
			Increased Water Use	0.2139	0.0178
	Sociopolitical	Social Costs	Earmarks/deficit increase	0.1624	0.0135
			Increased Lawsuits	0.0863	0.0072
			Infrastructure Wear +Tear	0.1243	0.0104
			Local Economy Collapse	0.6270	0.0523
Risks	Economic	Economic Risks	Local Economy Collapse	0.3774	0.0315
			Lost Potential Revenue	0.6226	0.0519
	Environmental	Environmental Risks	Contaminated Drinking Water	0.5968	0.0497
			Gas Leaks	0.2278	0.0190
			Increased Gas Consumption	0.1304	0.0109
			Well Explosions	0.0451	0.0038
	Sociopolitical	Social Risks	Excessive Policy	0.1024	0.0085
			Industrialization of Rural Areas	0.2882	0.0240
			Political Shift	0.0737	0.0061
			Public Affairs/Protests	0.5357	0.0446

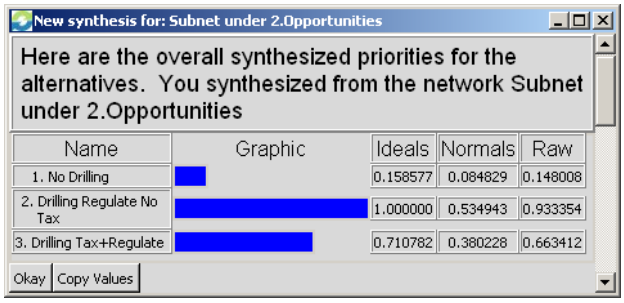
The Results

A synthesis was executed for each of the BOCR merit nodes. The results are depicted in the following table.

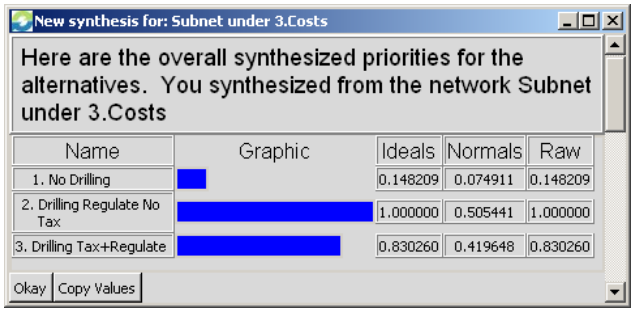
Benefits Synthesis



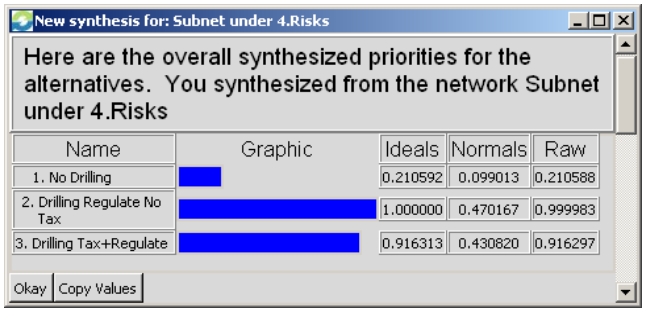
Opportunities Synthesis



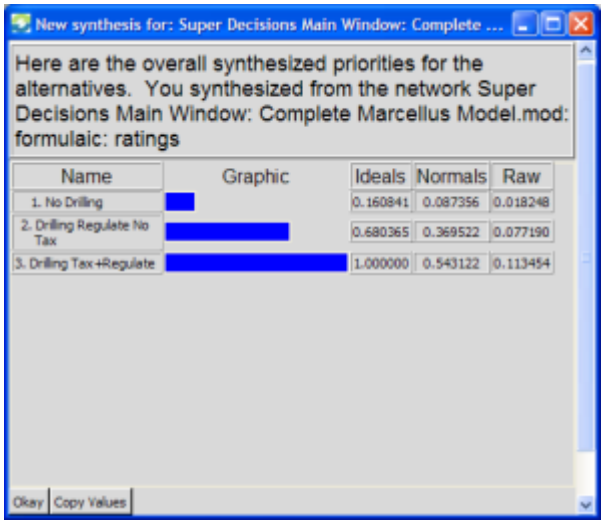
Costs Synthesis



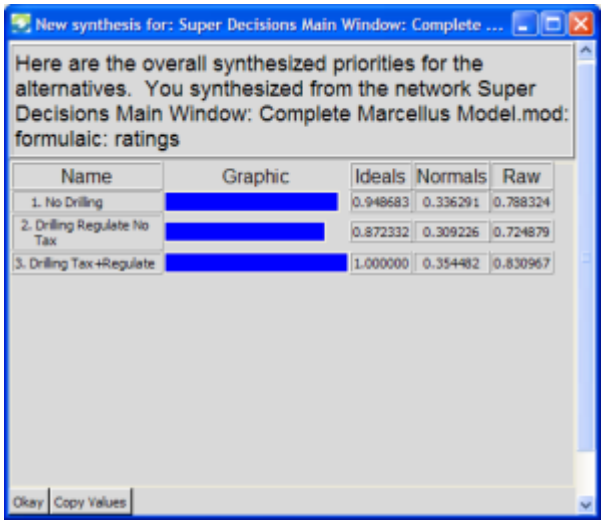
Risks Synthesis



Overall Model Synthesis – Additive



Overall Model Synthesis – Multiplicative



For the whole model synthesis, both the additive (negative) and multiplicative methods indicate that drilling with an added severance tax is the preferred alternative. This was the preferred alternative in the Benefits node and was lower in both costs and risks than drilling without severance tax. No drilling had the lowest benefits and opportunities but also had the lowest costs and risks. The final conclusion of the model then depends on the priority weighting of those four factors.

Sensitivity Analyses

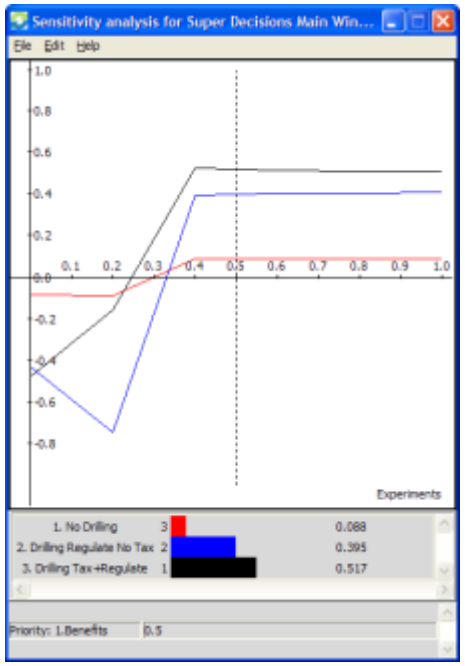
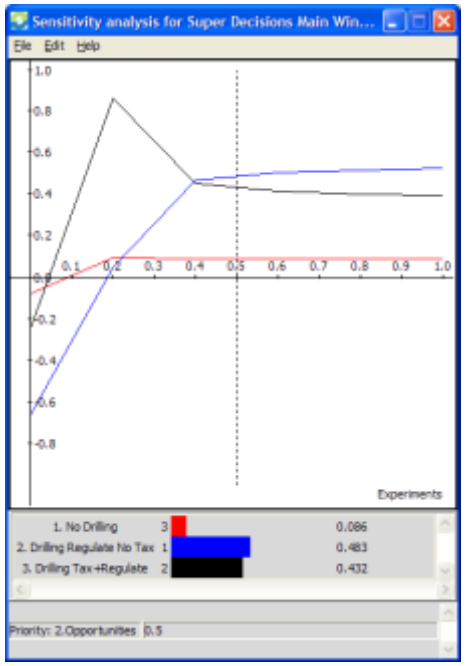
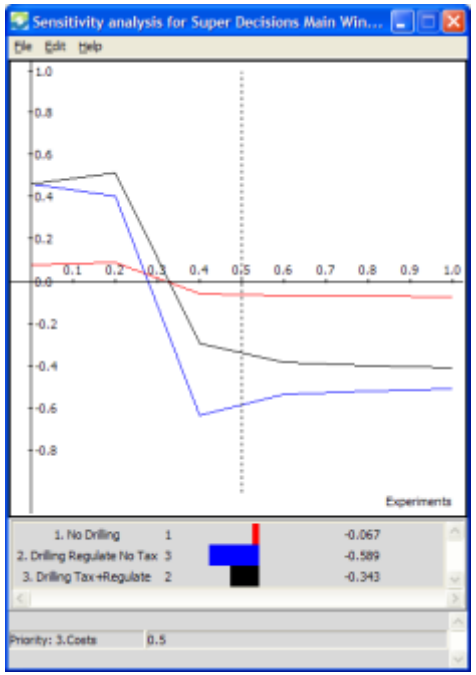
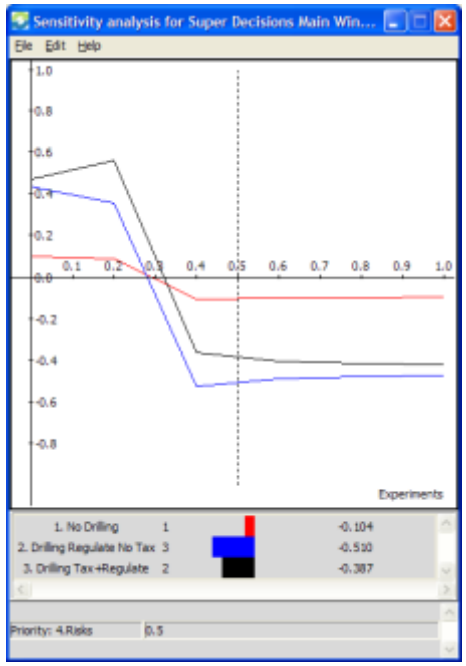
Benefits	Opportunities	Costs	Risks
			

Figure 04: BOCR Model Sensitivity Analysis with respect to each merit

When analyzing final goal selection, both of the increased drilling options vary significantly with changes in priority of benefits, opportunities, costs and risks. With very low emphasis on benefits, no drilling is the preferred option but as benefits become more heavily weighted it becomes the least attractive choice. High emphasis on costs or risks would lead to selection of no drilling as the preferred alternative as well.

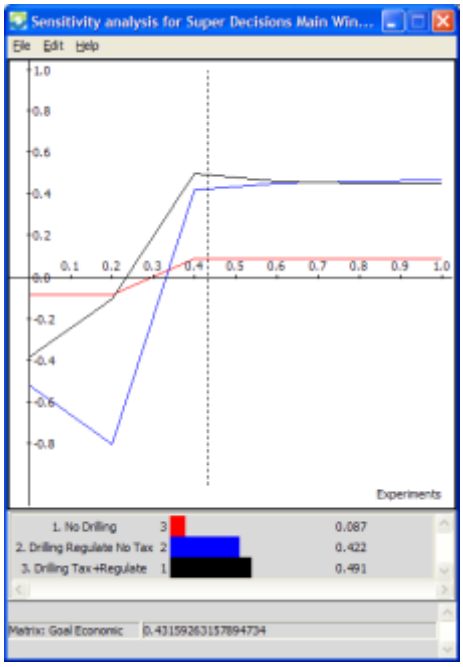
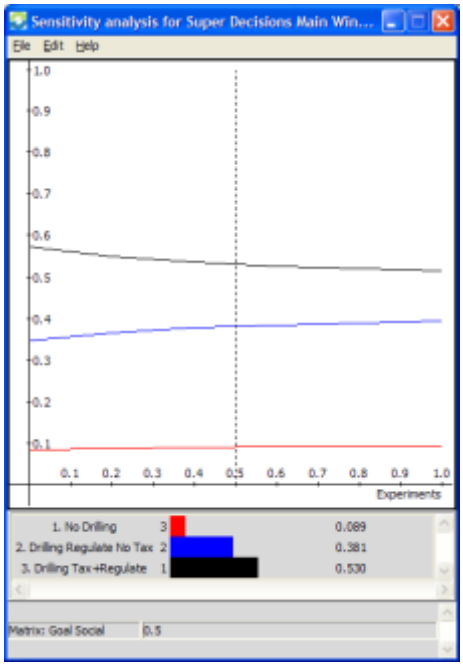
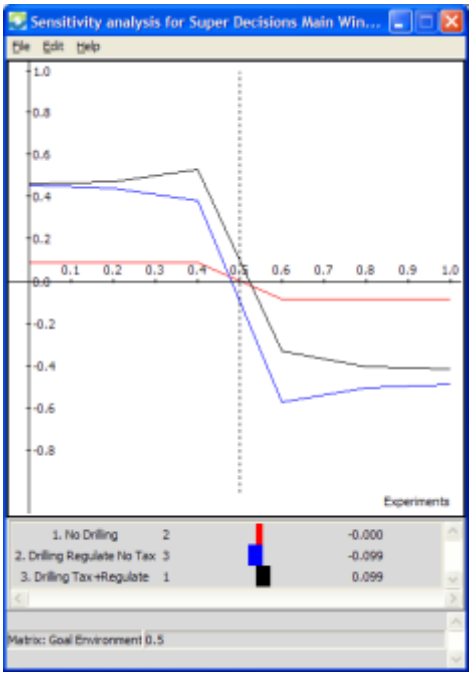
Economic	Social	Environmental
		

Figure 05: Overall Model Sensitivity Analysis with respect to each Strategic Criteria

When economic benefits are weighted heavily as the preferred strategic criteria, drilling with no severance tax overtakes drilling with tax as the preferred alternative. Similarly, as environmental concerns become more important the choice of no additional drilling becomes the preferred alternative. However, there is very little sensitivity in the model to preference toward social benefits. Drilling with a severance tax is the preferred option regardless of the importance of social impacts.