RE-FRACTURING THE APPALACHIAN BASIN:
An Economic Analysis

Kade Kiselica & Taylor Jennings
Marietta College
# Table of Contents

Abstract: ......................................................................................................................... 2  
Objective/Scope .................................................................................................................. 2 
Methods, Procedures, Process............................................................................................... 2 
Results, Observations, Conclusions................................................................................... 3 
Novel/Additive Information ............................................................................................... 3 
Introduction: ..................................................................................................................... 3 
Process: ............................................................................................................................. 4 
  Unconventional Assets ....................................................................................................... 5 
  Conventional Assets ......................................................................................................... 6 
Considerations for Re-fracture Candidates: ......................................................................... 7 
Performance Evaluation: .................................................................................................... 9 
Economics: ........................................................................................................................ 11 
  Creating Deterministic Model .......................................................................................... 11 
  Transitioning to Probabilistic Model ............................................................................... 13 
  Correlation Correction .................................................................................................... 14 
  Running the Simulation .................................................................................................. 15 
  Economic Analysis of Monte Carlo Simulation ............................................................... 15 
Gas Well Analysis .............................................................................................................. 15 
  Gas Well Undiscounted NPV ......................................................................................... 16 
  Gas Well Discounted NPV ............................................................................................... 19 
Oil Well Analysis ............................................................................................................... 23 
  Oil Well Undiscounted NPV .......................................................................................... 23 
  Oil Well Discounted NPV ............................................................................................... 25 
Economic Model Limitations: ............................................................................................. 28 
Conclusions: ..................................................................................................................... 29 
References: ......................................................................................................................... 30 
Appendix: .......................................................................................................................... 31
Abstract:

Objective/Scope
In the past ten years, hydraulic fracturing technology and strategies have made major improvements in the operational efficiency and economic performance of shale well completions. Much of this advancement was derived in the past three years as a response to the global downturn in oil and gas commodity pricing. Mature shale plays across the United States have a surplus inventory of horizontal wells employing highly inefficient completions styles. Amid the low oil pricing environment, operators in the Bakken and Eagle Ford were capable of revitalizing these prior generation wells with great success through re-fracturing programs. In many cases, production of these re-fractured wells rivaled the production of newly drilled and completed shale wells both in terms of initial production post re-fracture as well as extended interval cumulative production. These re-fracturing programs allowed producers to achieve tremendous gains in production while minimizing drilling activity. Although re-fracturing began as a highly economical method to improve production during a time of depressed oil pricing, it is still being used today to improve the production of additional wells recognized as top-tier candidates.

Methods, Procedures, Process
By developing a specific set of criteria to select wells for re-fracturing, the success of these programs can be employed in the Appalachian Basin to improve the economics of gas wells, mitigating the effects of highly discounted natural gas pricing. After the explanation of well candidacy, an economic sensitivity analysis can be implemented to illustrate the impacts of a strong re-fracturing program could make for operators in the Northeast through a comparison of public data showing production and total reserves for both in and out-of-basin re-fracturing programs. Additionally, while this paper focuses on re-fracturing as it relates to shale formations it also includes information as to how re-fracturing relates to conventional formations as well.
Results, Observations, Conclusions
After looking at the incremental economics of re-fracturing programs implemented in shale plays across the United States and in-basin data, the impacts of gas well re-completion can be fully quantified and understood through the application of probabilistic modeling. Additionally, this modeling further delineates re-completion candidacy by identifying which wells pose higher risks in economic metrics.

Novel/Additive Information
Very little information has been published regarding the impacts a re-fracturing program could have in the Appalachian Basin. As the field matures, the topic of re-completions will become increasingly important, and this analysis will allow operators to have a greater understanding of the impacts of re-fracturing shale gas wells in the Northeast.

Introduction:
Public data illustrates that, on average, shale wells see a 45-55% decrease in rate within the first 5-6 months following hydraulic fracturing. Additionally, as illustrated in Figure 1 on the following page, unconventional shale assets can be expected to see a 77-89% decrease in productivity three years after the original completion job (Asala, Ahmadi, & Taleghani 2016). This dramatically delays the ultimate recovery in shale and wells, implies that re-fracturing will remain important as the U.S. unconventional assets mature.
Of the potential methods for intervention, re-fracturing provides a quantifiable uplift in production while only costing a fraction (~25-40%) of the capitally intensive process to drill a new horizontal well (Asala, Ahmadi, & Taleghani 2016). As a result, re-fracturing provides the opportunity to affordably increase production and booked reserves. The impacts of re-fracturing shale wells on ultimate recovery and net present value will be discussed in further detail in the economics section of this paper. While conventional assets do not see the dramatic decline rates experienced in the unconventionals, re-fracturing still has the potential to uplift production and improve well economics.

**Process:**  
In order to understand the economic value of re-fracturing treatments, it is essential to understand the process behind the method as it relates to both unconventional and conventional assets.
Unconventional Assets
As a function of closure and damage to the induced fracture network, hydraulically fractured shale wells experience the dramatic declines in production, shown previously, after only a few short months following initial stimulation. This decline results in the need for an intervention to restore both the production and long-term economic performance of a shale well. Re-fracturing provides an economical solution to this problem and is particularly effective in dual porosity systems where the pumped slurry can: bypass formation damage, restore proppant that has been crushed or displaced by production, re-open the natural fractures, and increase stimulated reservoir volume (SRV) by forming new fractures. However, there are some important considerations regarding reservoir stress which need to be understood before conducting a re-fracturing operation.

Upon initial completion, the maximum horizontal stress is aligned perpendicular to the fractures, allowing for the maximization of SRV. However, due to reservoir depletion as the well is produced, the maximum and minimum horizontal stresses (σ_H & σ_h) reorient. During production, the maximum horizontal stress experiences a more rapid decrease than the minimum horizontal stress due to greater depletion in the direction of the fracture. This rapid decrease in maximum horizontal stress ultimately results in stress reversal near the fractures. With that said, this stress reversal is contingent on the overburden stress being sufficiently large compared to the horizontal stresses as well as the horizontal stress anisotropy being relatively small (Asala, Ahmadi, & Taleghani 2016). As a result, it can be expected that new fractures created by re-fracturing will propagate obliquely to the initial fractures. This occurrence plays an essential role in the effectiveness of re-fracturing campaigns for both conventional and unconventional applications. Furthermore, thermally induced stress can be taken advantage of when the cold re-fracturing fluid contacts the hot formation rock allowing for further development of micro-fractures and the re-activation of natural fractures present in the formation. It is also important to recognize that no existing hydraulic fracturing models accurately account for or predict the
initiation, propagation, or azimuth of re-fracturing treatments (Asala, Ahmadi, & Taleghani 2016).

All re-fracturing treatments, whether vertical or horizontal, can either utilize the existing perforation or have new perforations shot. However, there is an important difference in the effects of these two methods. When utilizing the existing perforations, or without effective isolation from the old perforations, the fracture would initiate along the primary existing fracture before re-orienting further into the reservoir past the zone of stress re-orientation discussed previously.

Fracture closure is the biggest cause of lost well productivity in unconventional wells. Initially, fracture closure is primarily a function of shale elasticity, but creep deformation becomes increasingly important as production progresses. In addition to re-opening the closed fractures, re-fracturing can be utilized to inject high strength proppant in the near-wellbore region to assist in the prolonged propping of the fractures. Frequently, high strength proppant is not economical in the initial completion job due to the majority of it being washed out during flow-back since the initial pressure depletion is so high. However, in the uplifted production of a re-fractured well, it may present additional value.

**Conventional Assets**
In regards to the general processes, in-situ stress reorientation, and causes of production decline: much of what holds true for re-fracturing operations in unconventional assets is also applicable in conventional assets. However, there are some differences in the re-fracturing design. Due to the higher reservoir permeability, re-fracturing to increase fracture length is largely ineffective according to a field stimulation study performed by Amoco. Rather, the performance of re-fracturing high permeability assets depends more greatly on bypassing formation damage and increasing the fracture conductivity. Increasing the conductivity can be achieved through the use of increased proppant size and concentration, application of higher...
quality proppants, and cleaner fracturing fluid (Reese, Britt, & Jones 1994). These short, fat fractures will provide improved sand control in the reservoir allowing for increased production rates. However, it is unlikely to expect any quantifiable increase in reservoir stimulation. Additionally, re-fracturing with an acid treatment could provide a noteworthy performance increase by dissolving the near-wellbore formation damage with hydrochloric or hydrofluoric acid. In the case of carbonate reservoirs, acid etching and wormholes can provide a more conductive fracture network.

Considerations for Re-fracture Candidates:
Since re-fracturing can either be employed to increase SRV or remediate near-wellbore formation damage, fully understanding the objectives of re-fracturing is essential to the design and procedure of the treatment. This decision is key in choosing whether new perforations should supplement the existing perforations to increase zonal coverage. Additionally, this functional understanding of the objectives leads to the choice of fluid volumes, fluid types, proppant concentrations, and a host of other design criteria (Asala, Ahmadi, & Taleghani 2016).

When considering well candidacy, several key metrics must be considered:

- Well Performance
- Well Depletion
- Proximity to Other Wells
- Original Completion Design
- Performance of Newer Offset Wells
- Wellbore Integrity
- Expected Re-Completion Costs

Uneconomical re-fracturing operations can generally be tied back to poor candidate selection. This fact is directly tied to the fact that re-fracturing cannot economically increase the performance of low grade geology. As a result of reservoir quality, wells exhibiting the best production rates and targeting the highest tier zones result in the lowest risk for re-fracturing. Additionally, the selection process must consider the depletion of the original well (Asala,
Ahmadi, & Taleghani 2016). Once again, geology and reservoir volumetrics are essential as re-fracturing a depleted well might create a short term increase in production, but still lack the recovery potential to pay off the operation when considering the incremental economics.

Well spacing is another piece of the primary candidacy selection for several reasons. Since re-fracturing serves as the primary substitute for infill drilling, the best candidates for re-fracturing are wells in areas with significant well spacing to be considered for infill drilling. Re-completing these wells with the most updated hydraulic fracturing designs and methods can serve to more economically stimulate the reservoir and reduce the quantity of more capital intensive infill projects required to completely access the reservoir. Furthermore, identifying the locations of nearby producing wells is important for a detail economic impact as those nearby producers will likely require frac-protect operations to be performed which generally entails a workover operation to de-complete the wells. As a result, the deferred production of these offset wells should be considered along with the workover expenses to fully grasp the economic impact.

Well history should be carefully considered when evaluating re-fracturing candidacy. Details of the original completion design become important factors in the understanding of candidacy. Additionally, the original operational details and comments should be reviewed to identify if issues were present during the initial fracturing job that would affect its overall performance. Newer offset wells with more modern completion designs are another important indicator of re-fracturing candidacy. As hydraulic fracturing has improved dramatically in the past several years, along with the lessons learned in newer wells across the field can be applied to aging wells. By reviewing the well performance of offset producers, it can become clear if that the well in question for re-fracturing is underperforming as a result of design or reservoir quality.

Wellbore integrity must be factor in consideration, while this is applicable to all wells, it is particularly applicable to an old production well. Without proper analysis of the condition and pressure ratings of the casing and tubing, if applicable, re-fracturing could severely damage the
well and present serious safety concerns. Finally, the costs of re-fracturing should be considered to determine if the projected incremental performance is economically viable.

**Performance Evaluation:**

Any re-fracturing operation poses four possible outcomes. According to Brady et. al. (2017), these outcomes are:

1. Additional Volume of Reserves
2. Accelerated Production of Reserves Previously Contacted
3. Loss of Reserves Previously Contacted
4. No Change in Production or Reserves

Following a re-fracturing operation, it is important to interpret the results of the performance to understand which of these outcomes is present and then draw hypotheses of how a re-fracturing program can impact future wells in the field. One of the best tools of analysis for this task is the application of a flowing material balance plot. These can be adopted for gas or oil reservoirs by plotting the normalized production rate vs. normalized cumulative production. By utilizing late time data in the flowing material balance, additional reserves or production can be quantified, shown on the following page in Figures 2 & 3. Clearly the cases of lost reserves and no change would result in a negative economic impact, but accelerating the production of previously contacted reserves can still deliver positive economic impacts as a result of discounted cash flows (Brady et. al. 2017).
Figure 2: Flowing Material Balance Showing Reserves Increase (Brady et. al., 2017)

Figure 3: Flowing Material Balance Showing No Additional Reserves (Brady et. al., 2017)
Economics:
A model was generated using probabilistic modeling software creating a Monte Carlo simulation. This means instead of generating a single number for an economic metric such as NPV, the model outputs a distribution of the range of values as well as the likelihood of those values. Also, the software allows for analysis of what inputs have the largest effect on each economic metric of the project. This proves to be very useful in candidate selection as well as data validation.

Creating Deterministic Model
The deterministic model consists of a base case, a re-fractured case, and an incremental case. The base case shows net present value from initial production without the initial CAPEX included. The CAPEX is excluded for two reasons. First, the data for initial well CAPEX is unknown and secondly the initial expenses will not affect the incremental economics because the values are the same. The base model utilizes modified-hyperbolic decline. This type of decline combines a hyperbolic decline with an exponential decline and is used to prevent overestimation of production by just using hyperbolic decline in shale reservoirs. In addition, when using modified-hyperbolic decline, the annual effective decline is calculated and compared to the terminal decline rate to determine when the decline switches from hyperbolic to exponential. See Figure 4 on the next page detailing the overestimation of reserves by hyperbolic decline as well as the time where the decline switches from hyperbolic to exponential.
Like the base case, the re-fractured case excludes initial well CAPEX, but this case does include the CAPEX associated with re-fracturing the well as this is the basis for evaluating the economic feasibility of recompletion. The re-fracture model also uses a modified-hyperbolic decline, but after the recompletion there is a second hyperbolic portion with a different hyperbolic exponent, b value, and a new initial production rate. Comparing this production decline curve to the base case yields Figure 5 on the following page.
When looking at Figure 5, the incremental production gain from re-completion is viewed as the area between the two decline curves. This portrays the basis of the economic analysis of recompletion where in order to be economical, the discounted value of incremental production increase must exceed the additional CAPEX required to recomplete the well.

Lastly, the incremental case is constructed by comparing production rates of the base case and the re-fracture case. Then, the incremental production is transitioned to a cash flow and discounted, and this case will serve as the most essential case in determining the economic viability of re-completion.

**Transitioning to Probabilistic Model**

Using the deterministic model discussed above and a probabilistic software, a Monte Carlo simulation was carried out. In order to run a Monte Carlo simulation, a distribution must be set for each monetary input such as gas price and variable OPEX as well as production inputs like hyperbolic exponents, IP rates, and time to recompletion. This process is done automatically by the probabilistic software for the production inputs because there are enough data points to create and fit a distribution. The software ranks the distributions for how well the data fits using three different advanced statistical regression parameters, and the distribution that had the
lowest average rank for the three parameters was chose to represent the input. However, for the economic inputs without having enough data, the average value was assumed to be similar to today’s pricing environment and an appropriate distribution was then fitted to the data. The last step before Monte Carlo simulation can begin is setting model outputs. For analysis, NPV, discounted NPV, profit to investment ratio (PIR), discounted PIR, Payout Period, Discounted Payout Period, maximum capital exposure (MCE), and internal rate of return (IRR) were set as the outputs in all three cases. But, because the base case has no CAPEX as discussed above the metrics PIR, Payout Period, MCE, and IRR do not apply to this case.

**Correlation Correction**

When using a Monte Carlo probabilistic model, for each trial, the software uses a different randomly generated probability to plug into each input parameter distribution and then runs the economics using all those inputs. However, one additional stipulation is the analysis assumes all inputs are independent of each other. For this model, the parameters are certainly dependent to each other, so correlations between each input must be developed. This process is very simple as each input parameter array is ranked where the max value is first. Then using Excel’s data analytics, a correlation matrix can be generated which displays correlation coefficients for relationships between each value. And, the correlation coefficient is the $\sqrt{r^2}$, which is applied to how well a trend line fits the inputted data, but the coefficient includes a negative sign if there is an inverse relationship between the two inputs. Once the correlation matrix is created and put into the model, the software calculates its random variables for each trial and then uses the correlation matrix to match inputs with similar cases to enhance the accuracy of the outputs. For example, without correlations a value close to the maximum of the initial production rate distribution could be selected for the same trial where a very low re-fracture IP rate was illogically selected. This example could also happen by giving vastly different hyperbolic exponents and decline coefficients that would generate illogical cases. See Appendix for correlation coefficient graphs.
Running the Simulation
Once all the inputs are correlated and the outputs are prepared, the software runs the economics 10,000 times randomly generating values for each input using their respective distributions and correlations. Then, the software plots the varying output values forming a normal distribution due to the large number of trials conducted. This allows for the creation of confidence intervals for each output whereas a deterministic analysis would only generate the mean of the given trials resulting in inaccurate outputs. The probabilistic model and thus confidence intervals do not ensure the accuracy of the outputs, but by giving a range of possible values the actual value of the output if the re-fracture was carried out is more likely to be in that range than the deterministic average of the limited trials conducted. Another portion of the results from the probabilistic model is the effect on an input on an output distribution. This allows the operators to improve the input, particularly monetary inputs, or ensure complete accuracy of the production inputs to refine the economics.

Economic Analysis of Monte Carlo Simulation
Two economic models were built to analyze both dry gas and oil wells. Oil well data was sourced from SPE 173340 which included decline parameters for re-completed wells in both the Bakken and Eagle Ford shales. Dry gas well data was developed from an array of public sources representing the average type curves for the Appalachian Basin. The two economic analyses are separated because of the large disparity in the price of the production as well as the possibility that the wells will react differently to recompletion based off production fluid type.

Gas Well Analysis
The probabilistic software generates an 80% confidence interval for each output as well as the mean and median values of the output distribution. Also, the software describes the inputs that had the largest effect on the output which can be useful for analyzing candidate selection.
Before analyzing the data, the output distributions must be understood. First, on the top left is the probability density distribution and shows where the output values fit with the range of outcomes on the x axis and a qualitative measure of likelihood on the axis. If the distribution were perfectly normal, this is where the characteristic Bell curve would appear. Secondly, the graph on the top right is the cumulative probability distribution showing the same range of outcome values on the x axis, but on the y axis is the probability of obtaining a value less than the corresponding x value. On both of these graphs, the black lines outline the boundaries of the industry standard 80% confidence interval where the x values outside this confidence interval are extremes and are not statistically significant. In addition, the graph on the bottom is a tornado chart which uses a baseline value for the distribution namely the mean and varies each input parameter to its minimum and maximum value individually and evaluates the output parameter value. On the graph, the largest input is given a lighter red color where the smallest input is given a darker red color.

**Gas Well Undiscounted NPV**
First, the NPV’s, discounted and undiscounted, will be evaluated. See the output distribution of undiscounted NPV as well as the input parameters impact on the following pages.
First, looking at the probability distribution, the 80% confidence interval of undiscounted NPV is (-3.83, 8.23) MM$. This means that eighty percent of the 10,000 trials had an undiscounted NPV between losing $3.83MM and making $8.23MM. The industry standard confidence interval (80%) means we are eighty percent confident that the incremental undiscounted NPV for recompletion of gas wells should be in that range. However, that confidence interval is not extremely significant because it includes positive and negative values. Instead, a metric that would make more sense to quantify is chance of failure or chance of success. This looks at the distribution and evaluated what percent of the data is above or below zero NPV. For example, a gas re-completion has a 38% chance of failure and thus has a 62% chance of success based on undiscounted NPV.

Two other simple metrics from the distribution are mean and median which can give an indication about the center of the distribution. For undiscounted NPV, the mean and median are $1.8MM and $1.3MM, respectively. In addition, the third graph discusses the input parameters.
that have the largest effect on undiscounted NPV. As modeled, the most important parameter on undiscounted NPV is the initial production rate after refrac. However, this parameter is not controllable by the operator, but returning to the correlations, the re-fracture IP is highly correlated to the initial IP. Again, the above analysis is based off undiscounted NPV’s, but most companies do not make decisions based off undiscounted cashflow. Instead, companies discount their cashflows at a rate similar to 10%. See the figure below detailing the distribution of discounted NPV’s (10% discount rate).

Gas Well Discounted NPV
Similar to the undiscounted NPV distribution, the discounted NPV distribution confidence interval includes both positive and negative values ranging from close to -$2.0MM to over $3.3MM. This makes sense as this value is just discounted cash flows from the first distribution and should have the same shape just a smaller spread as cash flow generated over time begins to be less valuable. The mean and median values for discounted NPV are $581,000 and $440,000 respectively. Additionally, the results indicate a 59% chance of success, discounted NPV greater than zero. These three results suggest that a gas recompletion could be an economic solution. Unsurprisingly, the parameters effect on the distribution are practically the same as the undiscounted NPV because the distributions are connected.

One noteworthy observation from the graphic is the low impact of pricing meaning that although pricing is important, it does not have a significant effect on the distribution. Next, looking at discounted PIR which is a metric used by companies to rank projects while taking out the scale of the project. See the distribution on Page 21.

Again, the 80% confidence interval contains positive and negative values ranging from negative 1.09 to positive 1.82. This yields a probability of success of 60%. The mean and median for the discounted PIR distribution are .326 and .217 respectively. Furthermore, this analysis shows the potential economic success of the recompletion of gas wells.
Oil Well Analysis

Oil well recompletion economics are similar to gas economics with highly different pricing and variable OPEX. The analysis will be done the same way as the gas analysis looking at undiscounted and discounted NPV followed by discounted PIR to evaluate the economic feasibility of oil well recompletion.

Oil Well Undiscounted NPV

As illustrated below in Figure 8, the confidence interval for oil well undiscounted NPV is (-1.65, 10.88) MM$. This has a much higher probability of success at 77% where using undiscounted NPV for gas wells the probability was only 62%. Additionally, the mean and median of the output distribution are $3.9MM and $2.9MM respectively. Also, by reviewing the effect on the mean, the only deviations from gas well modeling are: the time to re-fracture is significantly lower than in the gas analysis and the hyperbolic exponent, b, seems to have minimal effect in oil well recompletion economics.
Oil Well Discounted NPV
When the NPV is discounted the confidence interval becomes $-1.1\text{MM}$ to $4.9\text{MM}$, as shown on the following page. This is analogous to a 63\% chance of success which again renews that the majority of the confidence interval is mainly positive. Next, looking at the mean and median of $1.6\text{MM}$ and $1.2\text{MM}$, they are both optimistic on the economic feasibility of oil well recompletion. Also, pricing is ranked much higher in effect on the mean when the cash flows are discounted. Lastly, the oil well discounted PIR will be discussed.
Next, looking at the discounted profit to investment ratio distribution, the confidence interval ranges from negative .58 to positive 2.73. This yields a 75% chance of success as well as a mean and median of .908 and .713 respectively. Overall, the oil well recompletion economics are superior to that of gas wells. However, most likely this stems from the large disparity between commodity pricing. However, in all metrics, both oil and gas recompletions have higher than a 50% probability of success as well as a positive mean and median. This signifies the likelihood of economic success for recompletion.

**Economic Model Limitations:**
While this analysis was developed using an array of public data from horizontal unconventional wells, re-completion performance can be estimated for vertical shale wells by scaling down the results of this model to accommodate for the reduced CAPEX and inflow performance. Additionally, by considering the results on oil and dry gas wells, the results can be extrapolated to gain an understanding of re-fracturing economics and uplift in liquids-rich gas wells. However, this model is not analogous for conventional reservoirs as the re-completion design,
fracture development, and fluid-flow models will be vastly different in comparison to shale resource plays.

Conclusions:
Overall, re-fracturing programs present an opportunity for operators to gain additional production from existing wells. Through probabilistic modeling, numerous outcomes can be predicted to highlight the economic performance of re-fracturing both oil and gas wells. In regard to oil wells, an 80% confidence interval of discounted NPV resulted in a range from $-1.1 – 4.9 MM. In comparison, dry gas well modeling obtained a discounted NPV range of $-2.0 - 3.3MM when applying an 80% confidence interval. Furthermore, a candidate selection process was outlined using both qualitative and quantitative methods through probabilistic modeling. This analysis can be utilized to drive additional value from maturing dry gas and gas condensate wells in the Appalachian Basin.
References:


Appendix:

<table>
<thead>
<tr>
<th></th>
<th>Qi</th>
<th>QIr</th>
<th>bi</th>
<th>br</th>
<th>Di</th>
<th>DIr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qi</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>QIr</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>bi</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>br</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Di</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIr</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Figure 7: Correlation Coefficient Matrix