

SYSTEMS APPROACH AND QUANTITATIVE DECISION TOOLS FOR TECHNOLOGY SELECTION IN EFD

**Presented by
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OVERVIEW

- BACKGROUND
- PROBLEMS
- SYSTEMS APPROACH FOR DRILLING TECHNOLOGY SELECTION
- PROTOTYPE OF WEB-BASED APPLICATION
- BENEFITS OF THIS RESEARCH
- FUTURE TASKS

BACKGROUND

- Endeavor to minimize the environmental impact during drilling operations because they realize effectively managing environment will lead greater access to large potential reserves (20 billion barrels estimated by Dept. of Interior) in environmentally sensitive areas.



(Courtesy of Anadarko Petroleum Corporation)

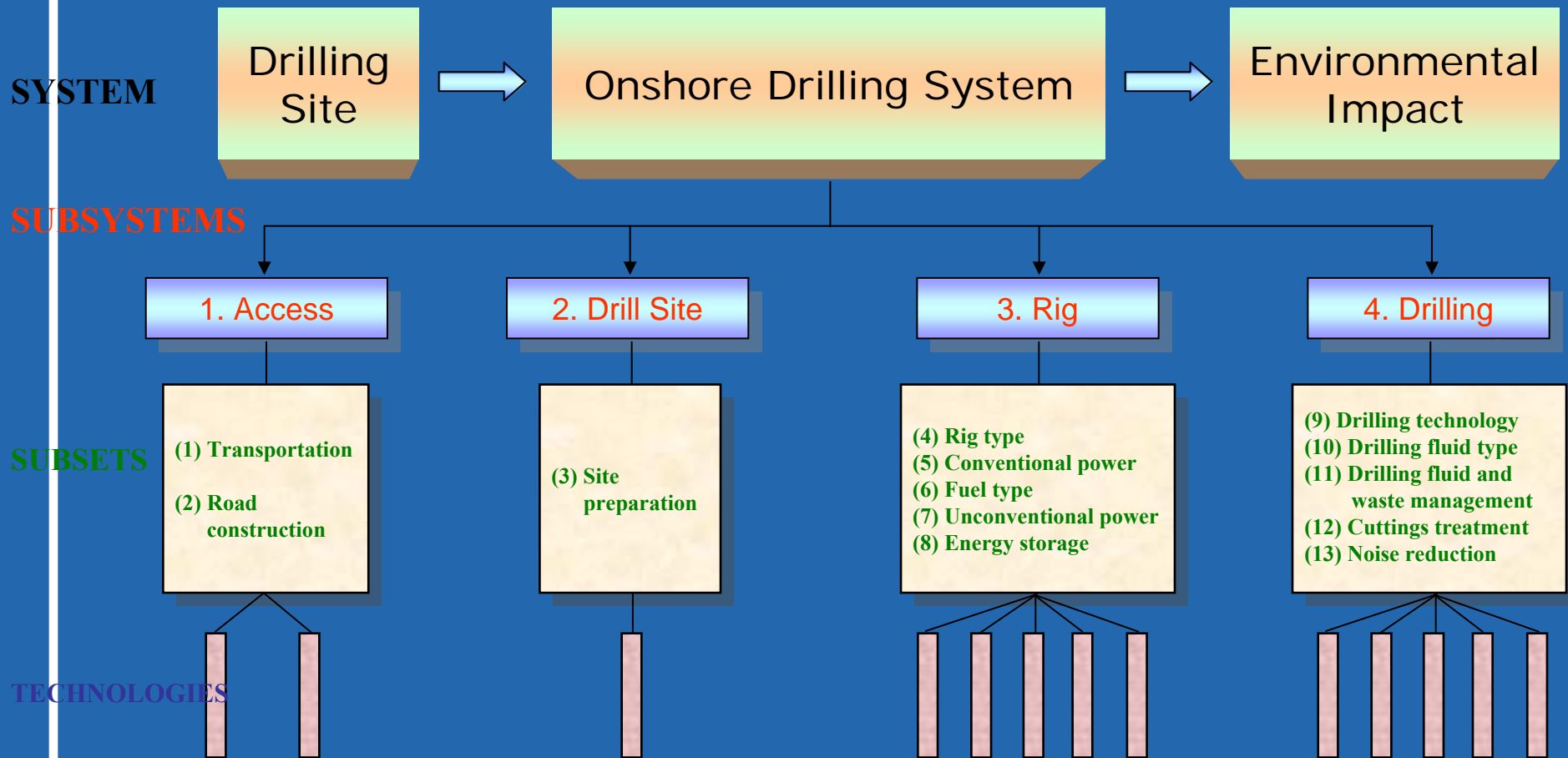
PROBLEM

- A number of EFD technology concepts have already been developed to varying degrees but few have been integrated into a field demonstrable drilling system compatible with ecologically sensitive area.
- It is difficult to select the best available drilling system for a given site because there are many possible systems and many different evaluation criteria.

RESEARCH OBJECTIVE

- Develop a technology evaluation protocol based on a systems analysis to incorporate a number of current and emerging technologies into a single drilling system with limited environmental impact.
- Suggest a small number of systems that should be particularly attractive for a given site.
- Help decision makers select the optimal system for a given site to minimize environmental impact and maximize profit
- Develop a web-based (ease to access and store) decision optimization tool to help decision makers easily follow the proposed technology evaluation procedure and then select an optimal system for a given site

INTRODUCTION OF SYSTEMS ANALYSIS



→ To select the optimal system (combination of technologies) to minimize impact and maximize profit

TECHNOLOGY SELECTION EXAMPLE

1. Access

(1) Transportation:

- Conventional diesel truck
- Rolligon
- Helicopter

(6) technologies

(2) Road construction:

- Gravel road
- Wood mat
- Dura-Base Composite mat

(16) technologies

Notes:
 (): Subsets
 • : Available technologies

2. Drill Site

(3) Site preparation:

- Gravel pad
- Composite mat
- Module + driven piles

(13) technologies

3. Rig

(4) Rig types:

- Conventional rig
- Rapid rig
- LOC 250

(5) Conventional power:

- Diesel engine
- Gas turbine
- Lean-burn natural gas engine

(6) Fuel types:

- Bi-fuel system
- Bio-diesel
- Bio-gas

(7) different technologies

(7) Unconventional power:

- Fuel cells
- Photovoltaic
- Wind turbine

(8) Energy storage device:

- Battery
- Capacitor banks
- Flywheel

4. Drilling

(9) Drilling technology:

- Conventional overbalanced
- Underbalanced drilling
- Managed pressure drilling

(10) Drilling fluid types:

- Oil-based mud
- Synthetic-based mud
- Water-based mud

(11) Drilling fluid and waste mgmt.:

- Closed loop + container
- Open reserve pit + equipment
- Lined reserve pit + equipment

(12) Cuttings treatment:

- Bioremediation
- Cuttings injection
- Evaporation and burial onsite

(10) different technologies

(13) Noise reduction:

- Construct a building
- Construct a wall
- Noise suppressor (engine itself)

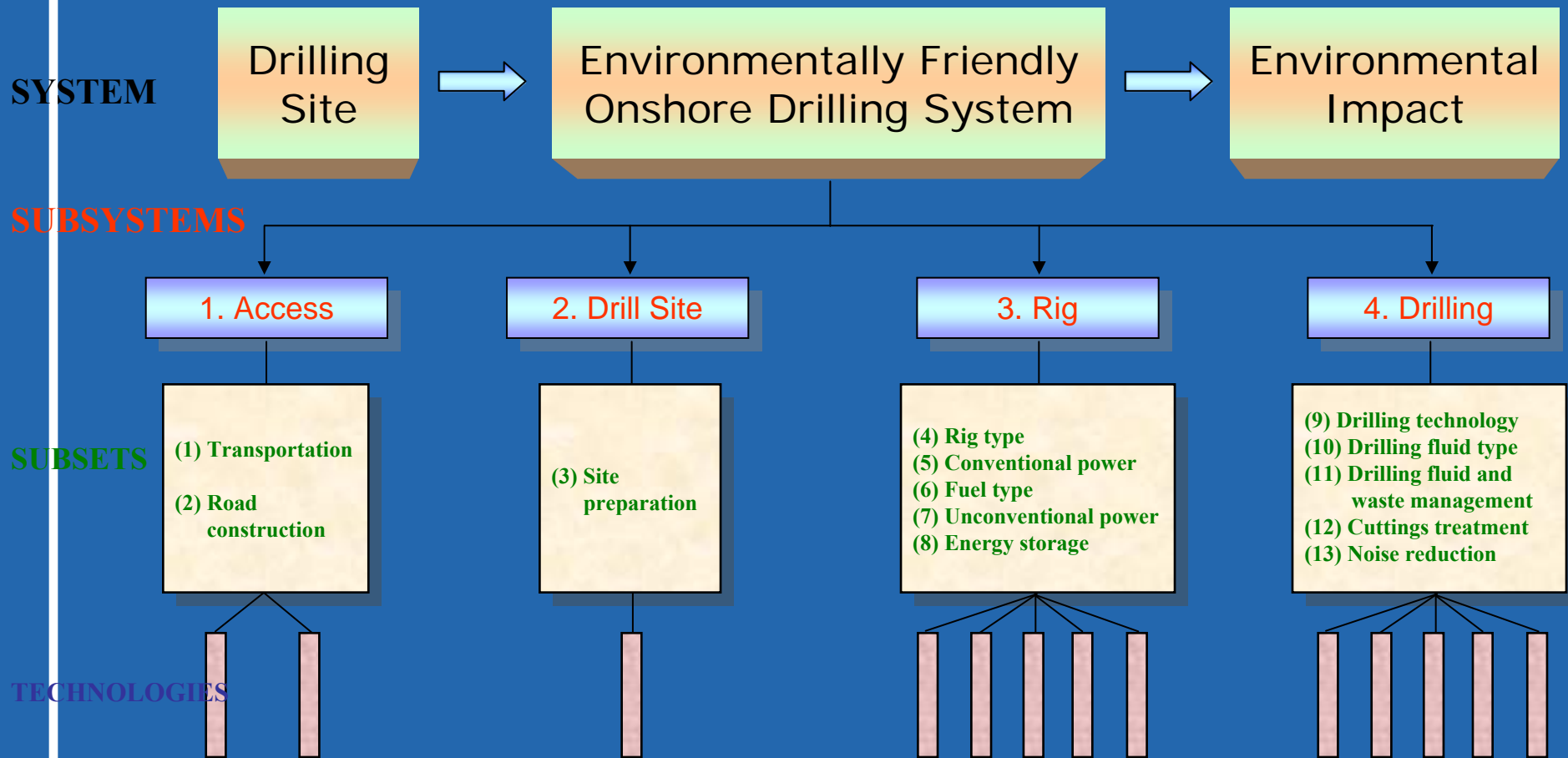
DEFINE ATTRIBUTE & UTILITY FUNCTION

Attribute: one of the parameters considered in the evaluation of the system (cost, land area, emission, and perception). Each attribute has an **attribute scale** used to score the technology on how well it meets the objective for this attribute (minimizes cost, land area, emission, and maximizes positive perception).

Utility Function: a relationship between the dimensional attribute score (e.g., \$, acres, and grades) and a non-dimensional number (between 0 and 1). The utility function is used to transform all scores into non-dimensional values between 0 and 1. This allows the decision maker to make all attribute scores uniform and comparable.

SYSTEMS ANALYSIS PROCESS

STEP 1 : Identify main subsystems, subsets, and technologies within each subset for drilling operations.



$\Sigma = 4$ subsystems including 13 subsets and +100 technologies

SYSTEMS ANALYSIS PROCESS [CONT.]

STEP 2 : Develop attribute and attribute scales to evaluate technologies.

- Technology total cost (x_1)
- Ecological footprint (x_2)
- Emissions:
 - Emissions of EPA and state regulated air pollutants (x_3)
 - Emissions of EPA and state regulated solid and liquid pollutants (x_4)
 - Emissions of EPA and state regulated noise pollutants (x_5)
- Perceptions:
 - Government regulators (x_6)
 - Industry decision makers (x_7)
 - The general public (x_8)
- Safety (x_9)

SYSTEMS ANALYSIS PROCESS [CONT.]

STEP 2 : Develop attribute and attribute scales to evaluate technologies.

- **Cost:** if purchasing, assume the resale value (80% in the case study) so as to estimate the total expenditure during the operation. On the other hand, if renting, a daily rate is required.
- **Footprint:** total used land area
- **Air emission:** three air contaminants (i.e., CO, Nox, and PM). The relative importance of those contaminants is CO (20%), Nox (40%), and PM (40%).

SYSTEMS ANALYSIS PROCESS [CONT.]

STEP 2 : Develop attribute and attribute scales to evaluate technologies.

- **Solid emission score (ordinal)**

Waste Management Technologies	Cuttings treatment	Solid/liquid emission score
Closed loop	Cutting injection	1.00
-	Bioremediation, Composting, In-situ vitrification, Land spreading, Plasma arc, Microwave technology	0.75
Lined reserve pit	Thermal desorption.	0.50
-	Chemical fixation and solidification	0.25
Open reserve pit	Evaporation and burial onsite	0.00

- **Noise emission score: according to Occupational Safety & Health Administration (OSHA), the eight-hour time-weight average sound level (TWA), in decibels, is recommended as the noise emission's scale.**

SYSTEMS ANALYSIS PROCESS [CONT.]

STEP 2 : Develop attribute and attribute scales to evaluate technologies.

- **Public perception score**

Description	Perception value
<i>Support.</i> No groups are opposed to the facility, and at least one group has organized support for the facility	1.00
<i>Neutrality.</i> All groups are indifferent or uninterested	0.75
<i>Controversy.</i> One or more groups have organized opposition, although no groups have action-oriented opposition (for example, letterwriting, protests, lawsuits). Other groups may either be neutral or support the facility	0.50
<i>Action-oriented opposition.</i> Exactly one group has action-oriented opposition. The other groups have organized support, indifference, or organized opposition	0.25
<i>Strong action-oriented opposition.</i> Two or more groups have action-oriented opposition	0

SYSTEMS ANALYSIS PROCESS [CONT.]

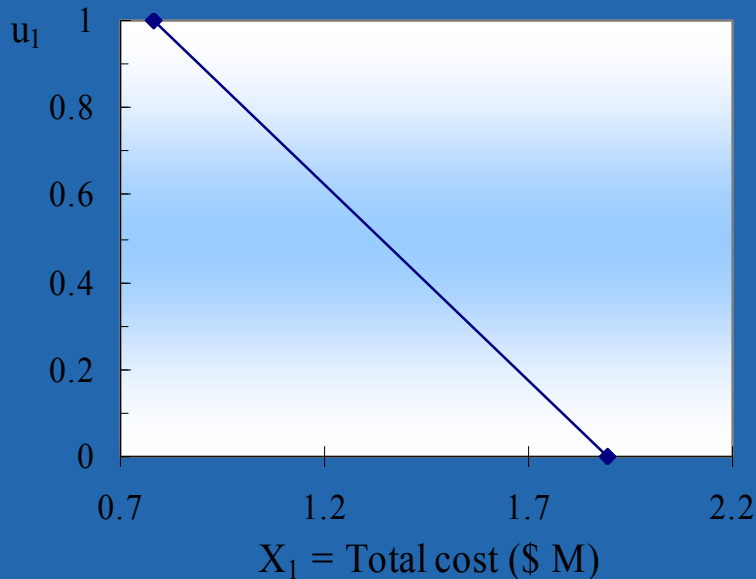
STEP 4

: For each attribute, calculate the overall attribute score of a system by adding the technology scores or selecting the minimum technology score.

Selected Technologies in Each Subset	Total Cost (\$)	Ecological Footprint (Acres)	Emissions			Perceptions			Safety Value
			Air	Solid & Liquid	Noise (TWA)	Gov.	Ind.	Public	
(1) Transportation: Conventional diesel truck						0.250	1.000	0.250	0.750
(2) Road construction: Gravel roads	\$148,500	3.030	0.566		98.562	0.250	1.000	0.250	0.500
(3) Site preparation: Gravel pad	\$137,813	2.812	0.598		98.019	0.250	1.000	0.250	0.500
(4) Rig type: Traditional older vintage rig	\$220,000		0.973		78.630	0.500	1.000	0.500	0.500
(5) Rig power (Conventional): Internal combustion engine	\$80,000		0.118		110.073	0.500	1.000	0.500	0.750
(6) Fuel type: Conventional diesel	\$94,080					0.500	1.000	0.500	0.500
(7) Rig power (Unconventional): N/A (0 %)	\$0	0.000	1.000		0.000	0.250	1.000	0.250	1.000
(8) Energy storage: N/A	\$0	0.000				0.250	1.000	0.250	1.000
(9) Drilling tech.: Conventional overbalanced drilling	\$204,000				116.700	1.000	0.500	0.500	0.500
(10) Fluid type: Water-based muds	\$47,940					1.000	1.000	1.000	1.000
(11) Waste mgmt.: Lined reserve pit + solid control equip.*	\$24,000	0.037		0.500		0.750	0.750	0.750	0.500
(12) Cuttings mgmt.: Cuttings injection	\$60,000			1.000		1.000	0.500	1.000	0.750
(13) Noise reduction: N/A									
Overall Attribute Scores (Σ or minimum value)	\$1,016,333	5.879	3.254	1.500	501.985	0.250	0.500	0.250	0.500

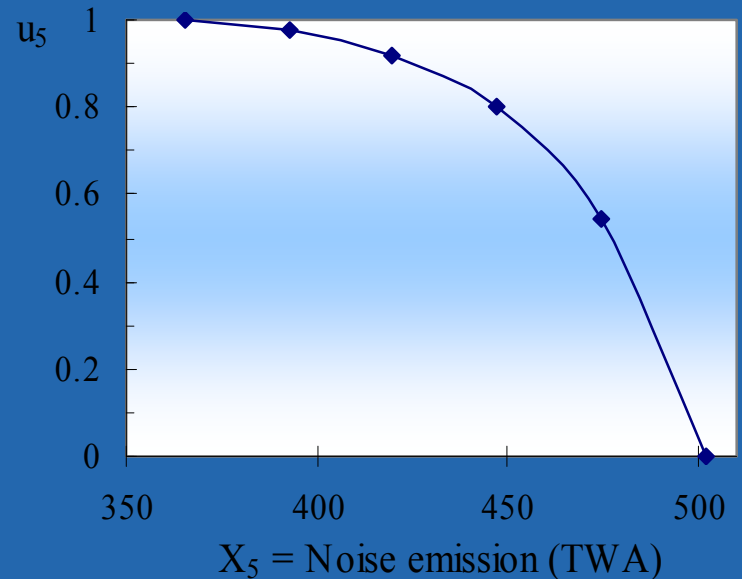
SYSTEMS ANALYSIS PROCESS [CONT.]

STEP 5 : For each attribute and in order to homogenize the scores, develop a "utility function (u_i)" to convert the overall dimensional score of a system (e.g, \$, acres, and grades) into a non-dimensional utility value (between 0 and 1) of the system.



$$u_1(X_1) = \frac{X_1 - \text{Worst Value}}{\text{Best Value} - \text{Worst Value}}$$

→ Linear Form



$$u_5(X_5) = a + b \times c^{X_5}$$

→ Exponential Form

SYSTEMS ANALYSIS PROCESS [CONT.]

STEP 5 : For each attribute and in order to homogenize the scores, develop a “utility function (u_i)” to convert the overall dimensional score of a system (e.g, \$, acres, and grades) into a non-dimensional utility value (between 0 and 1) of the system.

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Single Attribute Utility Values	0.788	0.000	0.000	0.600	0.000	0.250	0.500	0.250	0.500

SYSTEMS ANALYSIS PROCESS [CONT.]

STEP 6 : Decide on a weight factor (k_i) for each attribute (i).

Attributes	Weight Example
Total cost (x_1)	40 %
Footprint (x_2)	20 %
Air emission (x_3)	20/3 %
Solid/ liquid emission (x_4)	20/3 %
Noise emission (x_5)	20/3 %
Government perception (x_6)	5 %
Industry perception (x_7)	5 %
Public perception (x_8)	5 %
Safety value (x_9)	5 %

→ Weights must sum to one (the standard normalization technique used in decision analysis)

STEP 7 : Calculate the overall score of the system as " $\sum k_i u_i$ " (multi-attribute utility function).

SYSTEMS ANALYSIS PROCESS [CONT.]

- An example system

	Weights ($\Sigma = 100\%$ \therefore O.K!)								
	40%	20%	6.667%	6.667%	6.667%	5%	5%	5%	5%
Selected Technologies in Each Subset	Total Cost (\$)	Ecological Footprint (Acres)	Emissions			Perceptions			Safety Value
			Air	Solid & Liquid	Noise (TWA)	Gov.	Ind.	Public	
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Single Attribute Utility Values	0.788	0.000	0.000	0.600	0.000	0.250	0.500	0.250	0.500
\therefore Multi-Attribute Utility Value = 0.430									

SYSTEMS ANALYSIS PROCESS [CONT.]

STEP 8 : Use optimization technique (“Exhaustive Search Optimization”) to evaluate all systems and to find the best system (max. U-value) for a specific site.

→ “Exhaustive Search Optimization” is a simple, practical, and very robust method given the speed of modern computers (never converge on a local optimum far from the best fit)

STEP 9 : Conduct sensitivity analyses to examine the impacts of possible changes in the attribute scales, weight factors, and utility functions on the optimal system.

STEP 10 : Suggest a small number of systems (1~5) that should be particularly attractive for a given site.

PROTOTYPE OF WEB-BASED APPLICATION

1. Input scores (<http://efd.civil.tamu.edu/da>)

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Murphree WMA
Texas A&M University

EFD SYSTEMS > Murphree WMA > SUBSET #2
11/28/2008

LIST OF EVALUATED TECHNOLOGIES

TECHNOLOGIES	COST (\$)	FOOTPRINT (Acres)	EMISSION		PERCEPTION			
			Air	Solid/Liquid	Government	Industry	Public	
Composite mats	40000	3	0.7	0.7	1	0.6	1	Update <input type="button" value="X"/>
recycled well wastes	24000	5	0.5	0.75	0.75	0.5	0.4	Update <input type="button" value="X"/>
traditional gravel	12000	5	0.2	0.2	0.25	0.5	0	Update <input type="button" value="X"/>

SCORE INPUT TABLE [HOW TO SCORE ?]

TECHNOLOGIES	COST (\$)	FOOTPRINT (Acres)	EMISSION		PERCEPTION			
			Air	Solid/Liquid	Government	Industry	Public	
								<input type="button" value="Add"/>

PROJECT LISTS
LOGOUT

- Version [1.1]
- Has not been newly updated yet
- Seven attributes considered (not nine attributes)
- Total drilling time effect is not considered

PROTOTYPE OF WEB-BASED APPLICATION [CONT.]

2. Weight factors

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DECISION OPTIMIZATION

Transportation
Road Construction
Site Preparation
Rig Type
Conventional Rig Power
Fuel Type
Unconventional Rig Power
Energy Storage Device
Drilling Fluid Type
Drill Fluid & Cutting Mgmt.
Air Emission Control
Well Construction
Noise Reduction
Weight Factors
GET THE OPTIMAL SYSTEM

PROJECT LISTS
LOGOUT

Murphree WMA

Texas A&M University

EFD SYSTEMS > Murphree WMA > **WEIGHT FACTORS**

11/28/2008

LIST OF WEIGHT SCENARIOS

HOW MANY RESULTS?	PROPORTION OF UNCONVENTIONAL RIG POWER USAGE, P (0~60 %)	COST (w1)	FOOTPRINT (w2)	EMISSION		PERCEPTION			
				Air (w3)	Solid/Liquid (w4)	Government (w5)	Industry (w6)	Public (w7)	
The best system	0	0.4	0.2	0.05	0.05	0.15	0	0.15	Update X
The best system	10	0.2	0.2	0.05	0.1	0.15	0	0.3	Update X

WEIGHT SCENARIO INPUT TABLE [HELP ?]

HOW MANY RESULTS?	PROPORTION OF UNCONVENTIONAL RIG POWER USAGE, P (0~60 %)	COST (w1)	FOOTPRINT (w2)	EMISSION		PERCEPTION			
				Air (w3)	Solid/Liquid (w4)	Government (w5)	Industry (w6)	Public (w7)	
The best system	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	Add

Note: If you have more than 5 alternative technologies for each subset, the computing time will be significantly increased (would be more than 5 minutes). Remember, the more alternatives the longer computing time!

GET THE OPTIMAL SYSTEM QUIT

PROTOTYPE OF WEB-BASED APPLICATION [CONT.]

3. Results

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Murphree WMA

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DECISION OPTIMIZATION

EFD SYSTEMS > Murphree WMA > OPTIMAL SYSTEMS

11/28/2008

Transportation
Road Construction
Site Preparation
Rig Type
Conventional Rig Power
Fuel Type
Unconventional Rig Power
Energy Storage Device
Drilling Fluid Type
Drill Fluid & Cutting Mgmt.
Air Emission Control
Well Construction
Noise Reduction
Weight Factors
GET THE OPTIMAL SYSTEM

PROJECT LISTS
LOGOUT

LIST OF OPTIMAL SYSTEMS

SELECTED TECHNOLOGIES	COST (\$)	FOOTPRINT (Acres)	EMISSION			PERCEPTION			P (%)
			Air	Solid/Liquid	Government	Industry	Public		
Weight Scenario # 1	0.4	0.2	0.05	0.05	0.15	0	0.15	0	
Low impact transport	10000	0.5	0.2	0.6	0.75	0.75	1	1	
Composite mats	40000	3	0.7	0.7	1	0.6	1	1	
conventional	50000	3	0.2	0.2	0.3	0.5	0	0	
conventional rig	700000	3	0.3	0.3	0.4	0.5	0	0	
diesel/electric	100000	1	0	0	0.3	0.4	0	0	
regular diesel	10000	0	0.2	0.2	0.4	0.5	0	0	
oil base	30000	0	0.4	0.4	0.4	0.4	0.2	0.2	
Mud pit management	70000	0.25	0.6	1	1	0.6	1	1	
Catalytic reformers	20000	0.1	0.6	0.5	0.5	0.5	0.2	0.2	
vertical well	250000	3	0.4	0.4	0.3	0.5	0.1	0.1	
muffled power systems	20000	0.1	0.5	0.5	0.5	0.5	0.3	0.3	
Σ or Minimum value	1300000	13.95	0	0	0.3	0.4	0	0	
Utility Values (Risk-Neutral)	0.955	0.61	0	0	0.3	0.4	0	0	

Multi-Attribute Utility Value #1 = 0.5489

Weight Scenario # 2	0.2	0.2	0.05	0.1	0.15	0	0.3	10
Low impact transport	10000	0.5	0.2	0.6	0.75	0.75	1	1
Composite mats	40000	3	0.7	0.7	1	0.6	1	1
composite mats	200000	2	0.7	1	0.7	0.7	0.6	0.6
light weight rig	1000000	2	0.7	0.7	0.6	0.6	0.3	0.3
hybrid diesel electric	450000	0.9	0.55	0.55	0.7	0.2	0.4	0.4
regular diesel & battery	13500	0	1	1	1	0.8	1	1
Power from Grid	4000	0.02	1	1	1	0.5	1	1
Batteries	2500	0.025	1	1	1	0.5	1	1
oil base	30000	0	0.4	0.4	0.4	0.4	0.2	0.2
Mud pit management	70000	0.25	0.6	1	1	0.6	1	1
Catalytic reformers	20000	0.1	0.6	0.5	0.5	0.5	0.2	0.2
vertical well	250000	3	0.4	0.4	0.3	0.5	0.1	0.1
muffled power systems	20000	0.1	0.5	0.5	0.5	0.5	0.3	0.3
Σ or Minimum value	2110000	11.895	0.2	0.4	0.3	0.2	0.1	0.1
Utility Values (Risk-Neutral)	0.529	0.792	0.2	0.4	0.3	0.2	0.1	0.1

Multi-Attribute Utility Value #1 = 0.3891

SAVE RESULTS

QUIT

BENEFITS OF THIS RESEARCH

- Provide quantitative basis for suggesting alternative drilling systems.
- Explicitly evaluates alternatives against the criteria that are important in the situation.
- Use best available information – both expert knowledge and data – in a coherent, logical way.
- Can help the system implemented in a given situation to best meet the goals of the sponsor.

NEXT STEPS

- Get more EFD experts' inputs to make the procedure easier and quicker with more confidence.
- Keep the web-based application updated as the technology evaluation protocol has been continuously refined by EFD experts' comments.
- The utility values used in this research represent average estimates that reflect deterministic conditions possibly containing significant and sometimes varying uncertainty components.
- A new uncertainty-based methodology can be proposed as a future task for complementing the current technology evaluation protocol (Medina-Cetina et al. 2008).

QUESTIONS?

