$$
\begin{aligned}
&X + 8.18Y + 16.71Z \geq 9.91\\
&X + 5.47Y + 7.48Z \geq 0.02\\
&X + 4.30Y + 4.61Z \geq 0.11\\
&X + 4.20Y + 4.40Z \geq 3.79\\
&X + 3.12Y + 2.43Z \geq 1.46\\
&X + 3.17Y + 2.52Z \geq 10.64\\
&X + 7.44Y + 13.82Z \geq 0.02\\
&X + 5.86Y + 8.58Z \geq 0.19\\
&X + 4.38Y + 4.79Z \geq 1.87\\
&X + 4.09Y + 4.18Z \geq 0.12\\
&X + 3.84Y + 3.68Z \geq 4.36\\
&X + 3.37Y + 2.84Z \geq 8.64\\
&X + 7.28Y + 13.26Z \geq 0.73\\
&X + 5.89Y + 8.67Z \geq 0.41\\
&X + 4.54Y + 5.15Z \geq 1.41\\
&X + 4.07Y + 4.13Z \geq 0.00713
\end{aligned}
\tag{19}
$$

Where the last constraint was varied by selecting respective random combinations (summarized in Table 3.) of the controlling factor "**X**".

From Table 3 the orthogonal condition of $\{ x_{19}, x_1 \}$ should be chosen, because this choice leads to the smallest value of J (objective function). Table 3 also shows that applying fuzzy regression techniques, for solving a regression problem accounting for variations and unclear defined parameters, to all variable values (X, Y, Z, and J or optimal value) satisfies the "Positive Definite Property". The "Positive Definite Property" is defined as:

$$
\begin{aligned}
&X_i > 0,\\
&Y_i > 0,\\
&X_i\, Y_i - Z_i^2 > 0 \qquad \text{for all } i
\end{aligned}
\tag{20}
$$

As a result, combination $\{ x_{19}, x_1 \}$ thus satisfies the "Positive Definite Property" where D_A is defined as:

$$D_A^* = 58.26(15.89) - (-19.55)^2 > 0 \tag{21}$$

Although, the fuzzy regression yields to results that satisfy the assumptions defined by its theory, when compared to other methods applied in past experiments values for the objective function and covariance matrix were always significantly lower than the ones obtained with fuzzy regression. Then, it could be inferred that although our sample was chosen to be small (since fuzzy regression main theory relies on having reduced data sets) the randomness of the behavior of the factors (age and fume) is influencing the shelf-life of the gun propellants. Also, from Table 3 no pattern behavior seems to define the objective function nor its variable components.

To find the tendency and distribution for modeling the shelf-life of gun propellants following the fuzzy regression, 90 combinations repeating each variable exactly five times were randomly paired (refer to Table 4.). The linear programming problem defined before by Eq. (19) was solved with "LINDO" for each of the combinations by altering the last quality constraint to be representative of each individual combination from the group chosen. Since the 90 randomly selected combinations were forced to include exactly five times the value of each variable, for the goodness of establishing a patterned behavior to define the distribution the five values found for each combination were averaged.

Plots for each of the variable averages and standard deviations were done (refer to Figures 1-8). From Figures 1-4 a trend behavior could be observed in which maximum values occur at variables X4, X10, and X16. The behavior of the function seems to resemble an exponential form that tends to fade out as the number of variables is augmented. It needs to be pointed out that variation from the traditional distribution form is expected since we are dealing with fuzzy data sets. Therefore, an exact behavioral pattern distribution is not expected to be found.

of the function seems to resemble an exponential form that tends to fade out as the number of variables is

Standard deviation plots (refer to Figures 5-8) were sketched following the same procedure as the average plots per variable measured (refer to Figures 1-4). Results were almost identical, in which a trend was observed in all plots where maximum values were obtained at variables X4, X10, and X16. The plots then followed a stabilized fading pattern in which minimal activity was detected. It also seems that the overall cycle behavior was repeated starting from variable X35. Again, the behavior that Figures 5-8 seem to resemble is one of the exponential form with variations due to the uncertainty of our parameters.

CONCLUSIONS

The overall objective of this research was to introduce a new concept to model real life problems where data is not clearly ranged and/or defined, and apply this concept to model the shelf-life of gun propellants of the U.S. Navy.

From this research it could be concluded that although fuzzy regression thus take into account variability factors of associated uncertainties, sample size, etc. it does not clearly define or models a trend behavior which would make an accurate prediction of the shelf-life of the gun propellants. It was observed that fuzzy regression should not be implemented when the quality of the data is bad, that is when data, as it is in our case, presents high variability and/or outliners. It is therefore advisable to make use of probability conventional statistical regression analysis to predict and describe the behavior of the shelf-life of gun propellant ignoring extreme outliner points in the data set. In order to account for the possible non linearity relationship of the variables affecting the life of the gun propellants and the variation found from lot to lot, several equal samples could be modeled using both traditional statistical regression analysis as well as fuzzy regression analysis. Results should then be compared and commonality of results analyzed, from which conclusions of the distribution behavior should be drawn from that basis. By using an averaged of both results we can therefore account for the appropriateness of the regression model and its sample size.

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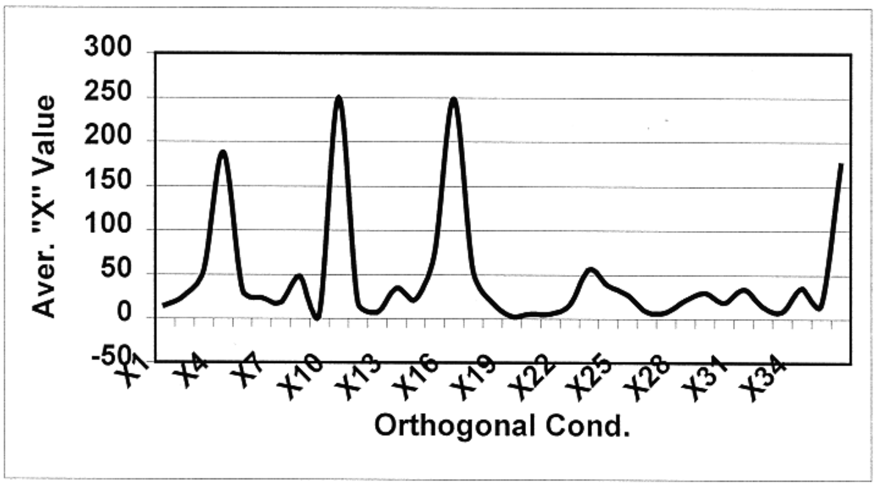

Figure 1. Plot of calculated averages of the "X" variable values.

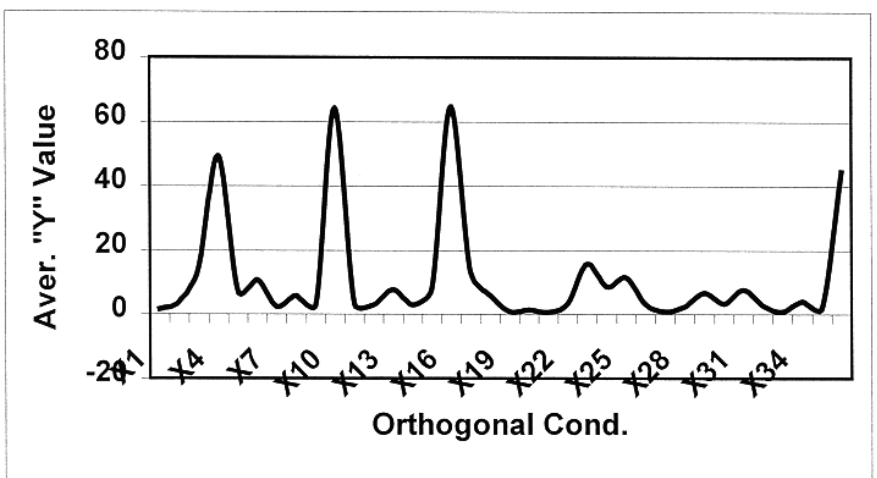

Figure 2. Plot of calculated averages of the "Y" variable values.

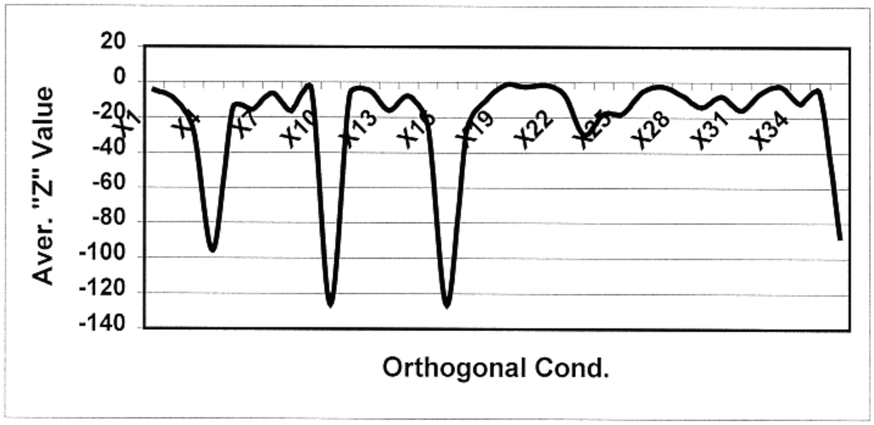

Figure 3. Plot of calculated averages of the covariance values of the function per variable.

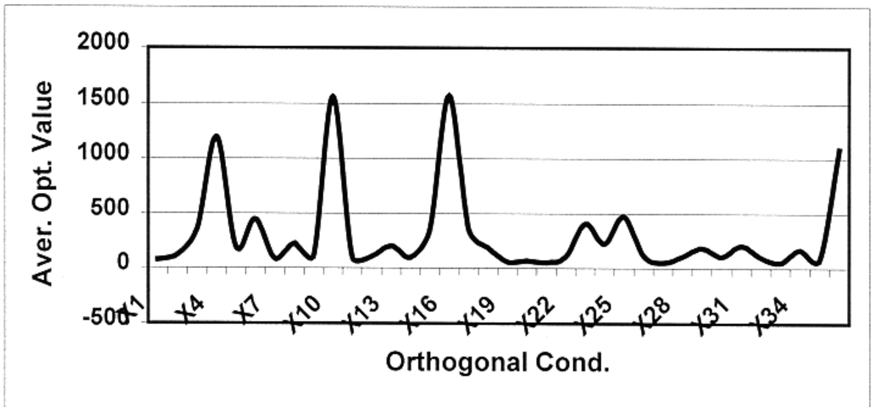

Figure 4. Plot of calculated averages of the optimal values of the function per variable.

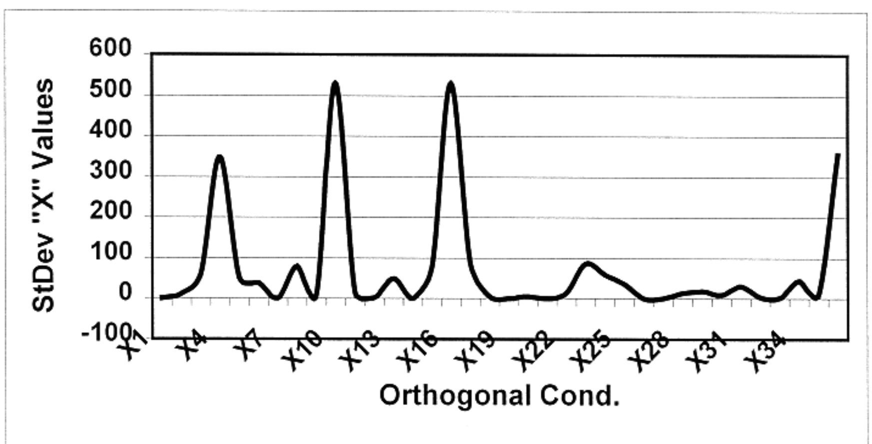

Figure 5. Plot of calculated standard deviation of the "X" variable values.

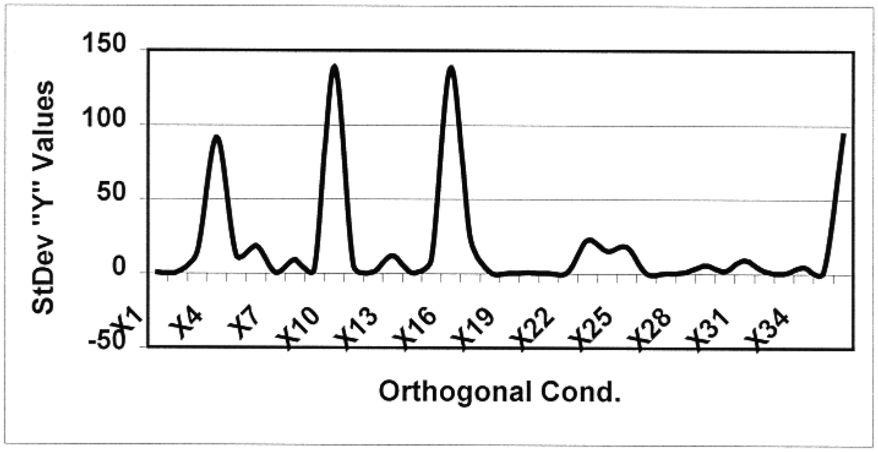

Figure 6. Plot of calculated standard deviation of the "Y" variable values.

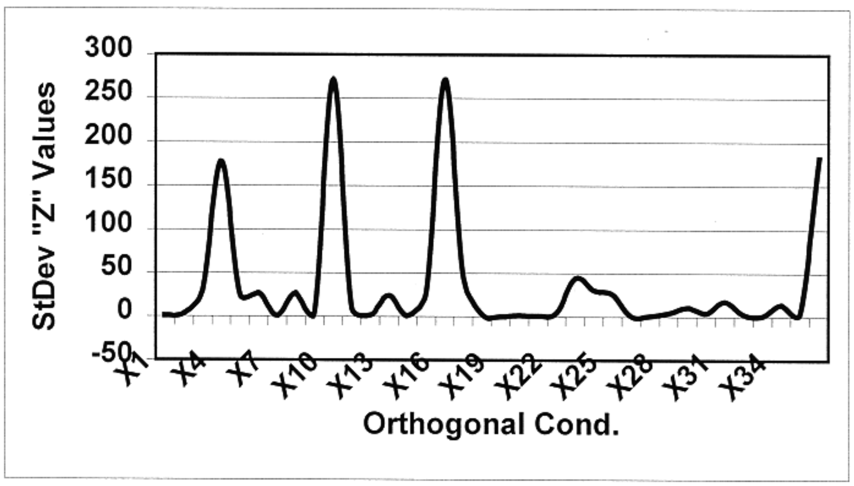

Figure 7. Plot of calculated standard deviation of the covariance per variable.

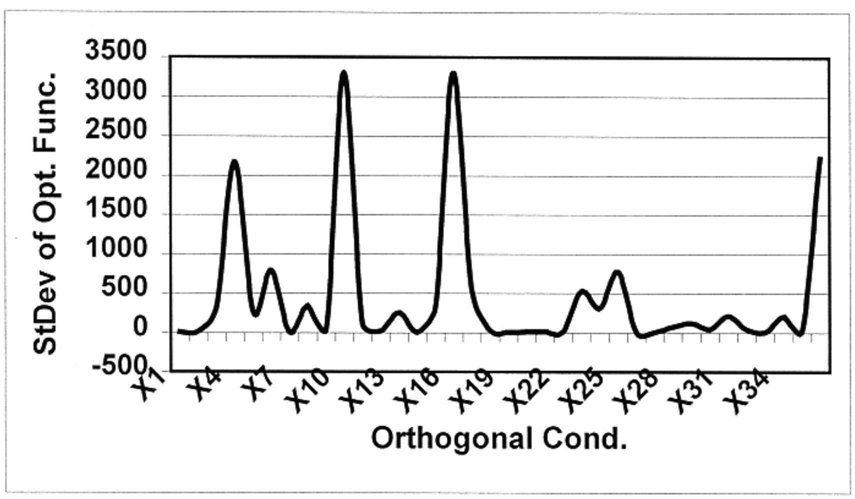

Figure 8. Plot of calculated standard deviation of the optimal function.

Table 1. Possibility vs. Probability Theories

Possibility distribution $\prod(x)$	Probability distribution $p(x)$
(Expert Knowledge)	(Frequency)
$\prod(A) = \max x \ \mu_A(x) * \prod(x)$	$P(A) = \int X_A(x)p(x)dx$
(μ_A: a fuzzy event)	(X_A: a crisp event)
Marginal possibility	Marginal probability
$\prod(x) = \max y \ \prod(x,y)$	$p(x) = \int p(x,y)\, dy$
Conditional possibility	Conditional probability
$\prod(x\|y) = k\prod(x,y)$	$p(x\|y) = p(x,y)/p(y)$
$(\max x \ \prod(x\|y) = 1)$	$(\int p(x\|y)dx = 1)$

Table 2. Observations of Age and Fume (Input – Output Data)

OBS	*AGE*	*FUME*
1	5.0247	3.06027
2	8.0849	2.74521
3	10.8274	2.03014
4	12.8548	1.88493
5	14.7397	1.94521
6	17.0904	1.58356
7	4.8521	2.95069
8	7.8027	2.85753
9	10.6575	2.03288
10	12.6877	1.87123
11	14.5589	1.87671
12	16.4329	1.51233
13	17.4329	2.20822
14	4.6384	2.86575
15	7.5041	2.97534
16	10.4767	2.01918
17	12.4932	1.91507
18	14.4082	1.74521
19	16.1507	0.05205
20	18.6658	1.30685
21	4.7836	4.08767
22	8.8685	2.73425
23	11.6000	2.14795
24	13.7479	2.09863
25	15.8438	1.55890
26	17.4027	1.58630
27	3.8932	3.71781
28	7.6082	2.92877
29	10.5370	2.18904
30	12.7233	2.04384
31	14.7671	1.91781
32	16.6822	1.68493
33	3.7041	3.64110
34	7.3425	2.94521
35	10.2877	2.26849
36	12.5534	2.03288

Table 3. Random Combinations of X & Results Obtained Applying Fuzzy Regression Analysis

Orthogonal Condition	Obtained "X" Value	Obtained "Z" Value	Obtained "Y" Value	Optimal Value of Function
x_1, x_3	728.81	-253.92	90.76	3505.20
x_{36}, x_{25}	531.63	-303.81	176.36	5686.84
x_3, x_3	967.27	-532.11	293.86	8215.20
x_{25}, x_{17}	926.19	-510.58	282.78	7976.75
x_{13}, x_{33}	369.17	-110.08	34.18	2386.65
x_6, x_{28}	793.53	-279.81	100.95	3706.49
x_{19}, x_1	58.26	-19.55	15.89	2153.84
x_{33}, x_2	427.12	-118.71	33.15	2864.33
x_{23}, x_{35}	26845.10	-11517.99	4941.36	102501.69
x_{10}, x_5	4778.78	-2587.71	1402.83	37314.32

Table 4. Results from Solving the LP Problem with Random Combination Pairs

Orthogonal Condition	*Obtained "X" Value*	*Obtained "Y" Value*	*Obtained "Z" Value*	*Obtained Value Of Function*
X1, X11	14.7	1.68	-4.93	70.87
X1, X16	15.21	1.76	-5.14	72.44
X1, X20	13.68	1.52	-4.52	67.68
X1, X13	16.29	1.93	-5.57	75.82
X1, X32	14.23	1.61	-4.75	69.41
X2, X17	29.62	4.03	-10.9	117.26
X2, X26	7.47	2.87	-4.61	104.12
X2, X29	31.16	4.27	-11.52	122.08
X2, X35	31.81	4.37	-11.78	124.1
X2, X36	30.18	4.12	-11.12	119.02
X3, X18	19.48	6.05	-10.83	172.32
X3, X24	142.77	35.01	-70.71	785.08
X3, X26	8.7	3.21	-5.27	111.53
X3, X31	89.49	23.83	-46.17	575.03
X3, X32	13.81	4.59	-7.95	141.2
X4, X21	5.86	0.516	-1.65	48.8
X4, X23	60.65	16.3	-31.4	401.59
X4, X26	10.67	3.74	-6.3	122.98
X4, X29	52.42	13.76	-26.81	335.55
X4, X36	808.92	211.52	-413.35	5052.62
X5, X12	6.72	2.65	-4.2	99.46
X5, X13	121.18	28.74	-58.9	649
X5, X14	21.87	2.81	-7.8	93.18
X5, X19	3.33	1.1	-1.72	64.56
X5, X21	5.99	0.53	-1.7	49.05
X6, X17	9.82	3.51	-5.85	118.01
X6, X22	7.39	2.85	-4.56	103.62
X6, X24	4.39	1.98	-2.93	84.86
X6, X25	91.82	43.41	-63.32	1851.72
X6, X27	6.72	0.61	-1.95	50.51
X7, X11	17.98	2.2	-6.24	81.06
X7, X25	17.03	2.05	-5.87	78.12
X7, X31	18.14	2.22	-6.31	81.59
X7, X35	20.69	2.62	-7.33	89.5
X7, 36	18.73	2.31	-6.54	83.39
X8, X13	24.24	3.18	-8.75	100.55
X8, X15	187.68	21.63	-63.71	821.77
X8, X20	3.37	1.43	-2.09	72.22
X8, X27	10.34	1.01	-3.21	57.72
X8, X28	14.82	1.59	-4.86	68.54
X9, X23	3.85	5.86	-7.04	186.36
X9, X25	7.64	2.92	-4.7	105.2
X9, X32	13.79	4.58	-7.93	141.06
X9, X33	7.99	0.752	-2.39	53.04
X9, X36	-8.37	0.951	1.09	68.63
X10, X12	7.24	2.8	-4.49	102.71
X10, X14	21.51	2.75	-7.66	92.06
X10, X15	17.11	2.06	-5.9	78.37
X10, X16	1196.6	312.66	-611.23	7462.28
X10, X21	5.83	0.513	-1.64	48.74
X11, X27	7.26	0.671	-2.13	51.58

Table 4. Results from Solving the LP Problem with Random Combination Pairs (Continued)

X11, X29	43.14	11.74	-22.48	293.16
X11, X33	7.66	0.716	-2.27	52.39
X12, X17	6.9	2.71	-4.3	100.58
X12, X18	11.02	4.16	-6.76	146.69
X12, X22	5.49	2.3	-3.53	91.72
X13, X20	3.38	1.57	-2.26	75.8
X13, X26	8.01	3.03	-4.9	107.52
X14, X30	22.46	2.9	-8.04	95
X14, X31	21.73	2.79	-7.74	92.75
X14, X36	24.07	3.15	-8.68	100.01
X15, X19	3.27	0.56	-1.11	51.55
X15, X28	45.78	4.27	-14.06	236.68
X15, X34	113.74	12.06	-37.06	535.82
X16, X26	8.78	3.23	-5.31	111.96
X16, X32	13.91	4.62	-8	141.77
X16, X33	7.96	0.749	-2.38	52.98
X17, X23	205.56	54.1	-105.37	1302.32
X17, X34	18.33	2.25	-6.39	82.17
X18, X25	17.08	6.39	-10.43	221.23
X18, X30	19.24	5.98	-10.71	171.01
X18, X31	24.09	7.22	-13.18	197.49
X19, X24	3.32	0.989	-1.59	61.8
X19, X30	3.32	1.03	-1.64	62.74
X19, X35	3.31	0.88	-1.47	59.18
X20, X29	3.39	1.58	-2.26	75.9
X20, X34	6.47	0.584	-1.86	50.01
X21, X23	3.37	1.4	-2.06	71.66
X21, X35	6.81	0.621	-1.98	50.68
X22, X24	31.47	4.32	-11.64	123.03
X22, X25	6.66	2.64	-4.17	99.07
X22, X30	31.18	4.27	-11.52	122.12
X23, X27	7.87	0.739	-2.35	52.8
X24, X27	7.75	0.725	-2.31	52.56
X28, X30	19.64	2.46	-6.91	86.22
X28, X32	18.12	2.22	-6.3	1.52
X28, X33	11.14	1.09	-3.46	60.65
X29, X34	20.2	2.55	-7.13	87.97
X31, X34	18.35	2.25	-6.39	82.22
X32, X33	7.6	0.676	-2.15	51.67
X32, X34	17.53	2.13	-6.07	79.67
X34, X35	20.91	2.66	-7.42	90.18

Table 5. Calculated Averages per Random Combination

Orthogonal Condition	*Average "X" Value*	*Average "Y" Value*	*Average "Z" Value*	*Average Opt. Value*
X1	14.822	1.7	-4.982	71.244
X2	26.048	3.932	-9.986	117.316
X3	54.85	14.538	-28.186	357.032
X4	187.704	49.1672	-95.902	1192.308
X5	31.818	7.166	-14.864	191.05
X6	24.028	10.7472	-15.722	441.744
X7	18.514	2.28	-6.458	82.732
X8	48.09	5.768	-16.524	224.16
X9	4.98	3.0126	-4.194	110.858
X10	249.658	64.1566	-126.184	1556.832
X11	18.148	3.4014	-6.752	103.702
X12	7.474	2.924	-4.656	108.232
X13	34.62	7.69	-16.076	201.738
X14	22.328	2.88	-7.984	94.6
X15	73.516	8.116	-24.368	344.838
X16	248.492	64.6038	-126.412	1568.286
X17	54.046	13.32	-26.562	344.068
X18	18.182	5.96	-10.382	181.748
X19	3.31	0.9118	-1.506	59.966
X20	6.058	1.3368	-2.598	68.322
X21	5.572	0.716	-1.606	53.786
X22	16.438	3.276	-7.084	107.912
X23	56.26	15.6798	-29.644	402.946
X24	37.94	8.6048	-17.836	221.466
X25	28.046	11.482	-17.698	471.068
X26	8.726	3.216	-5.278	111.622
X27	7.988	0.751	-2.39	53.034
X28	21.9	2.326	-7.118	106.722
X29	30.076	6.78	-14.04	182.932
X30	19.168	3.328	-7.764	107.418
X31	34.36	7.662	-15.958	205.816
X32	14.19	2.8452	-6.09	99.138
X33	8.47	0.7966	-2.53	54.146
X34	35.77	3.9968	-11.908	168.73
X35	16.706	2.2302	-5.996	82.728
X36	174.706	44.4102	-87.72	1084.734

X33 8.47 0.7966 -2.53 54.146

Table 6. Calculated Standard Deviations per Random Combination

Orthogonal Condition	*StDev "X" Values*	*StDev "Y" Values*	*StDev "Z" Values*	*StDev of Opt. Func.*
X1	0.99688	0.16	0.4	3.11
X2	10.42	0.61	3.02	7.84
X3	59.15	14.18	29.02	304.85
X4	348.12	90.99	177.92	2162.89
X5	50.48	12.1	24.74	256.83
X6	37.95	18.44	26.55	788.61
X7	1.36	0.21	0.54	4.23
X8	78.4	8.91	26.5	334.44
X9	8.27	2.23	3.66	54.25
X10	529.4	138.92	271.16	3301.31
X11	14.71	4.71	8.88	106.24
X12	2.09	0.72	1.23	21.9
X13	49.04	11.79	24.05	250.44
X14	1.04	0.16	0.41	3.21
X15	76.71	8.76	25.97	328.88
X16	530.01	138.68	271.03	3295.02
X17	85.16	22.81	44.12	535.87
X18	4.75	1.12	2.31	28.46
X19	0.02	0.21	0.24	5.09
X20	4.47	0.42	1.09	10.77
X21	1.29	0.38	0.56	10.02
X22	13.61	0.95	4.12	14.05
X23	86.88	22.36	44.03	521.57
X24	59.72	14.83	29.84	316.24
X25	35.99	17.93	25.62	773.83
X26	1.21	0.33	0.64	7.11
X27	1.39	0.15	0.49	2.77
X28	13.74	1.21	4.1	73.36
X29	19.26	5.58	10.33	122.09
X30	10.08	1.88	3.91	41.41
X31	30.92	9.28	17.12	212.06
X32	4.19	1.72	2.38	40.37
X33	1.5	0.17	0.53	3.68
X34	43.97	4.59	14.24	205.84
X35	11.61	1.53	4.3	29.13
X36	354.84	93.43	182.1	2218.2

X33 1.5 0.17 0.53 3.68

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GENERAL SESSION IV (1115 - 1200)

**Conceptual Issues in Model Assessment:
What Can We Learn From Past Mistakes?**

Naomi Oreskes
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In recent years, there has been growing recognition that complex models of natural systems cannot be validated, and that the term validation is misleading from both scientific and regulatory standpoints. From a regulatory standpoint, problems arise because of differences in the way the term validation is interpreted by expert and lay communities. From a scientific standpoint, problems arise when we assume that model validation provides confirmation of the underlying scientific conceptualization.

Most efforts at model validation concentrate on comparing model output with the natural world. While such comparisons can be useful, they do not provide adequate basis for confidence in the accuracy of the model. There have been many cases in the history of science of models that made accurate, quantitative predictions, but were later shown to be conceptually flawed. This paper examines three examples. In each case, the conceptual flaws were not apparent to their designers and users, yet appear obvious in retrospect. Furthermore, because the flaws were conceptual, quantitative assessment of model accuracy would not have revealed the underlying problems. Hindsight suggests that conceptually flawed models may still be useful for the immediate predictive problems for which they were designed, but they are not reliable for understanding processes and structures. A well-confirmed model may thus be acceptable for a design or problem-solving purpose, as long as that purpose does not require comprehension of underlying causes.

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