Advanced Modeling in Commercial Asset Management Systems

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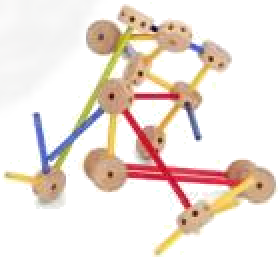
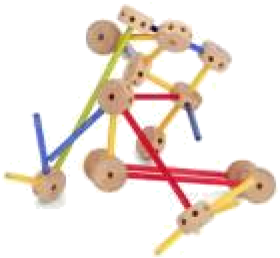


Topics

- Why
- What
- How
- When

- Modeling Theory
- Data Preparation
- Deterministic Modeling
- Probabilistic Modeling
- Revisiting your models

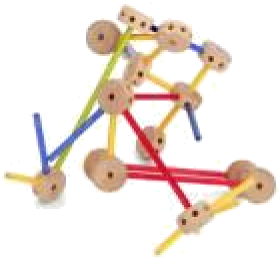


y = mx + b is an engineer's best friend…

… unfortunately engineers don't have very many friends, and so even their best ones don't visit very often.

Modeling Theory

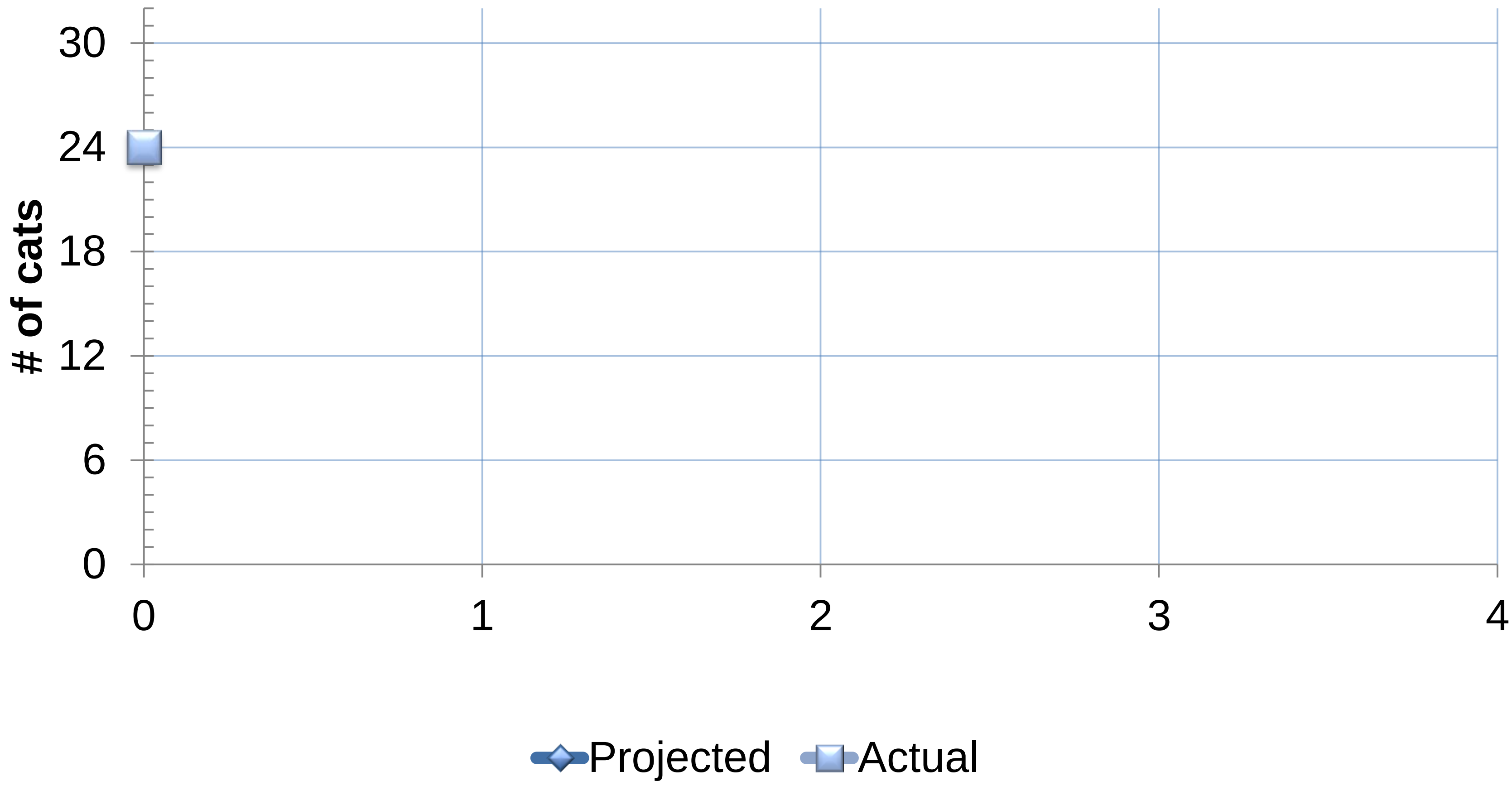
- Why do we model?
  - To accurately predict the future condition state of our assets in our infrastructure network. *(kind of)*
  - We use this information to determine the best way to maintain these assets throughout their entire life at the lowest possible cost. *(typically)*



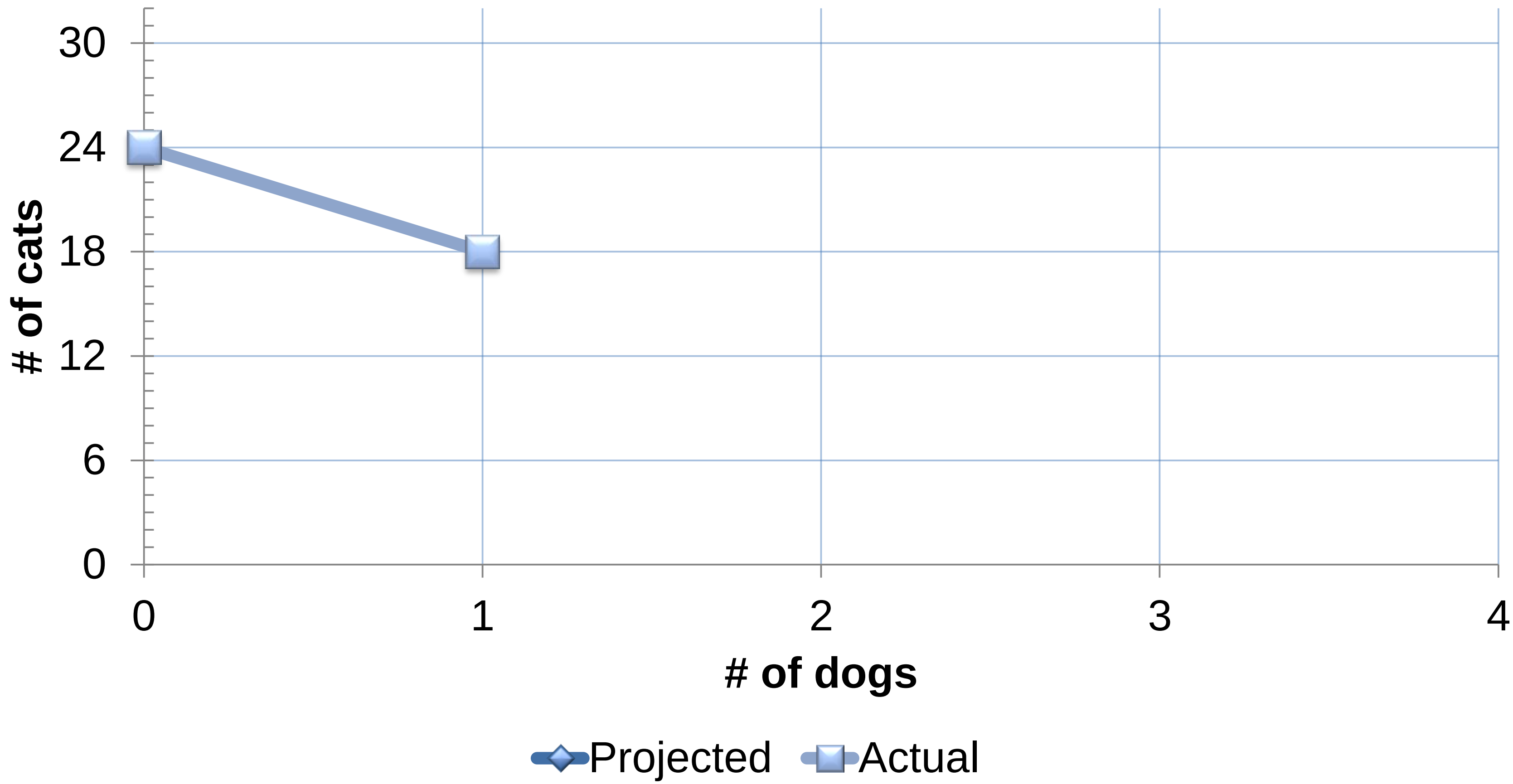
Modeling Theory

- Ultimately, we want to fulfill an Objective Function, while satisfying a set of Constraint Criteria.
- Using customizable decision trees, these objective and constraint criteria functions can become quite complex, especially when trying to preserve pavement rather than simply rehabilitating it.

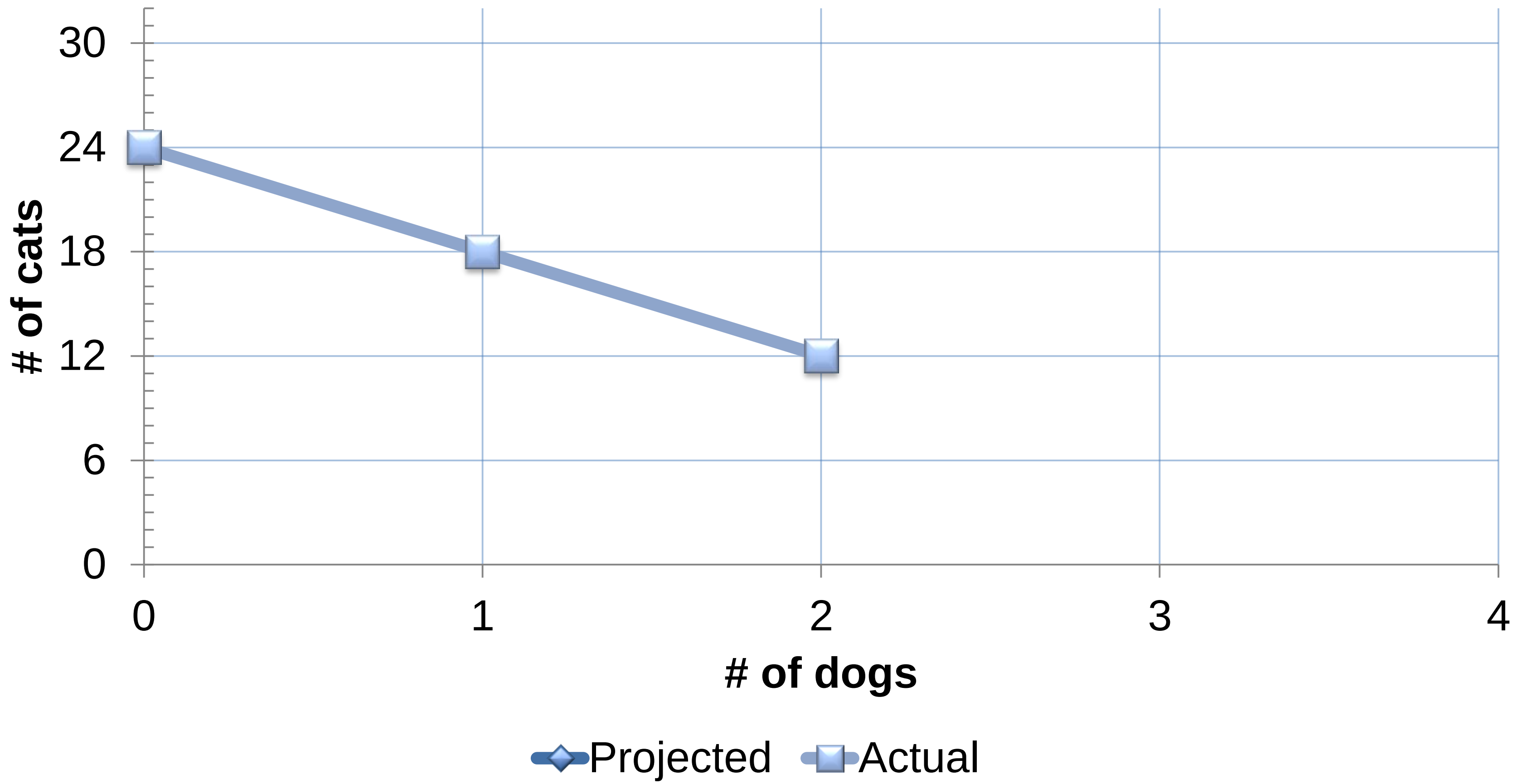
Highly Technical Theoretical Example



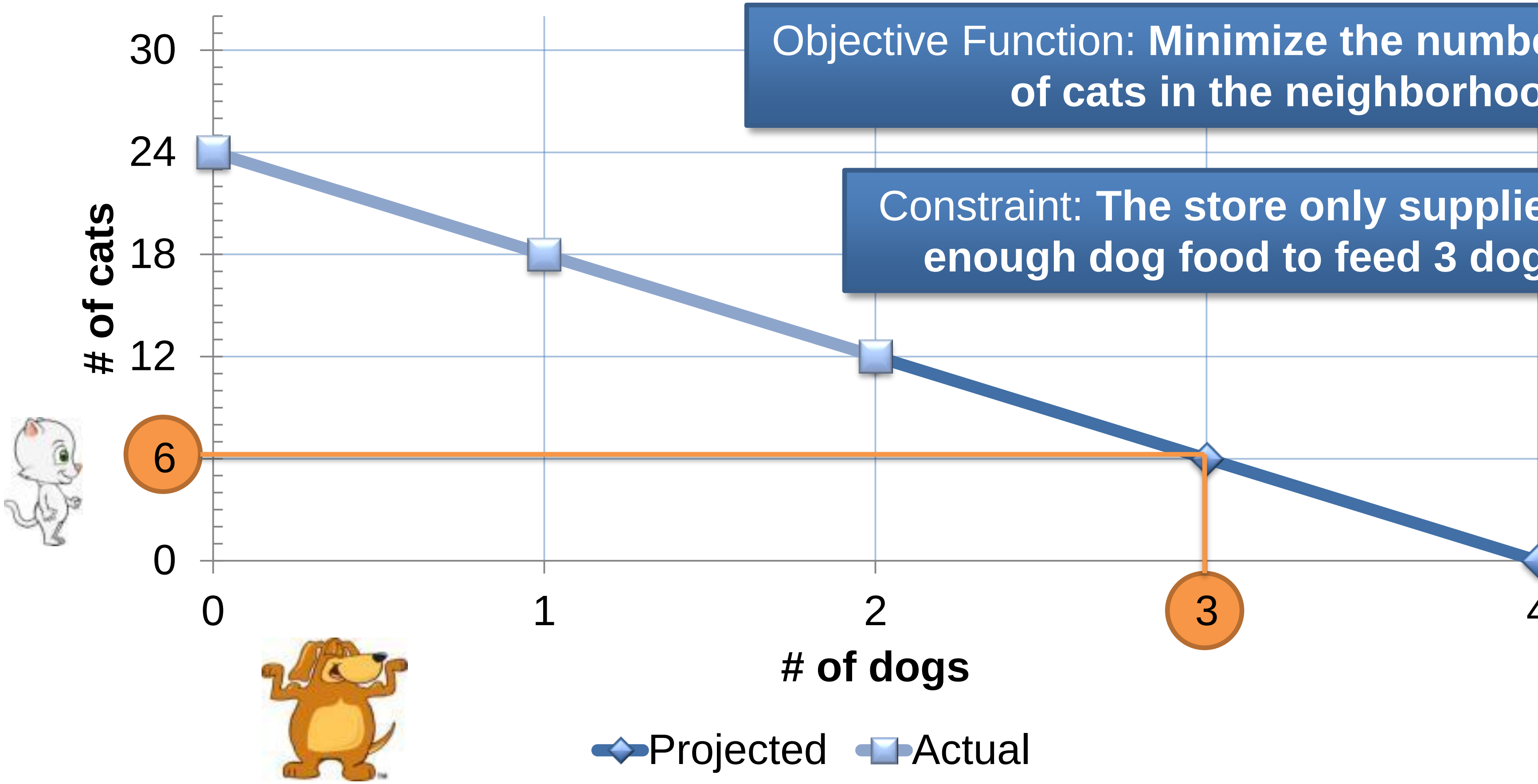
Highly Technical Theoretical Example



Highly Technical Theoretical Example



Highly Technical Theoretical Example



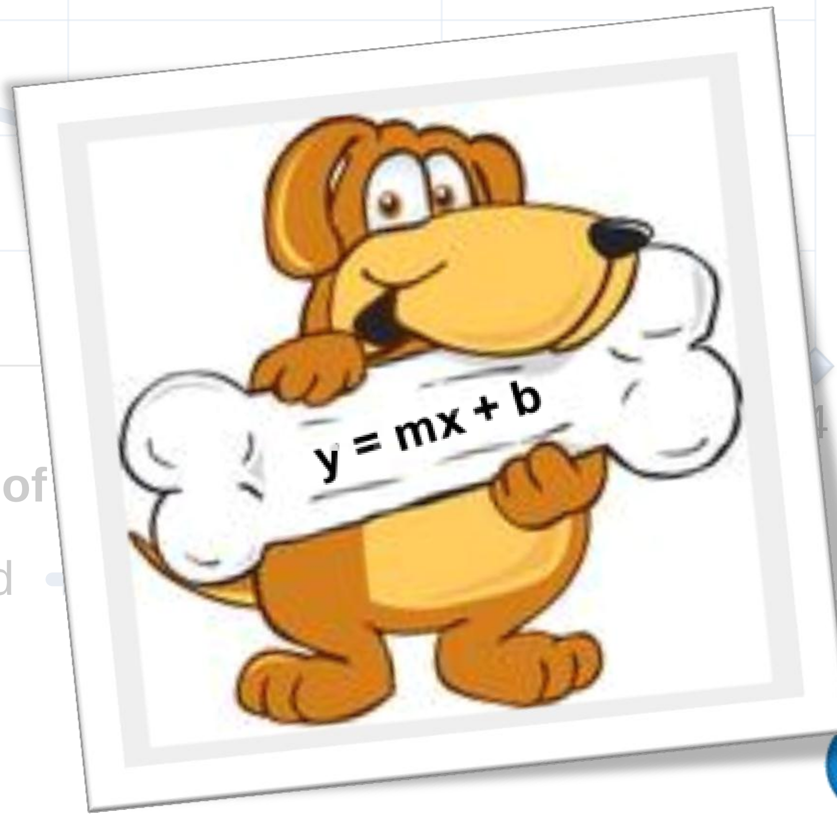
Objective Function: **Minimize the number of cats in the neighborhood**

Constraint: **The store only supplies enough dog food to feed 3 dogs**

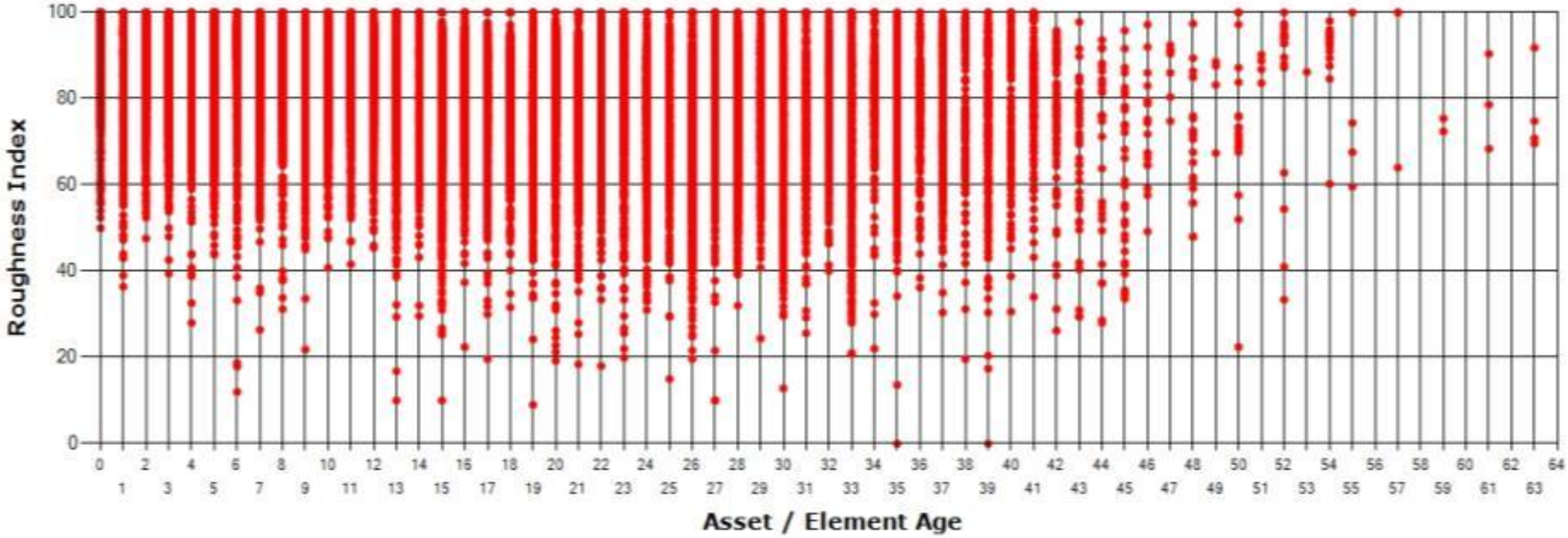
Optimized Result: **The neighborhood will still have to deal with 6 voracious cats**

What Have We Learned?

- $cats_{QUANTITY} = (-6) * dogs_{QUANTITY} + 24$
- *y = mx + b is an engineer's best friend. (maybe dogs too…)*
- *… but the real world isn't that simple.*



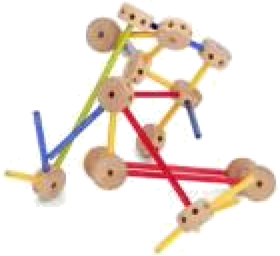
The Real World



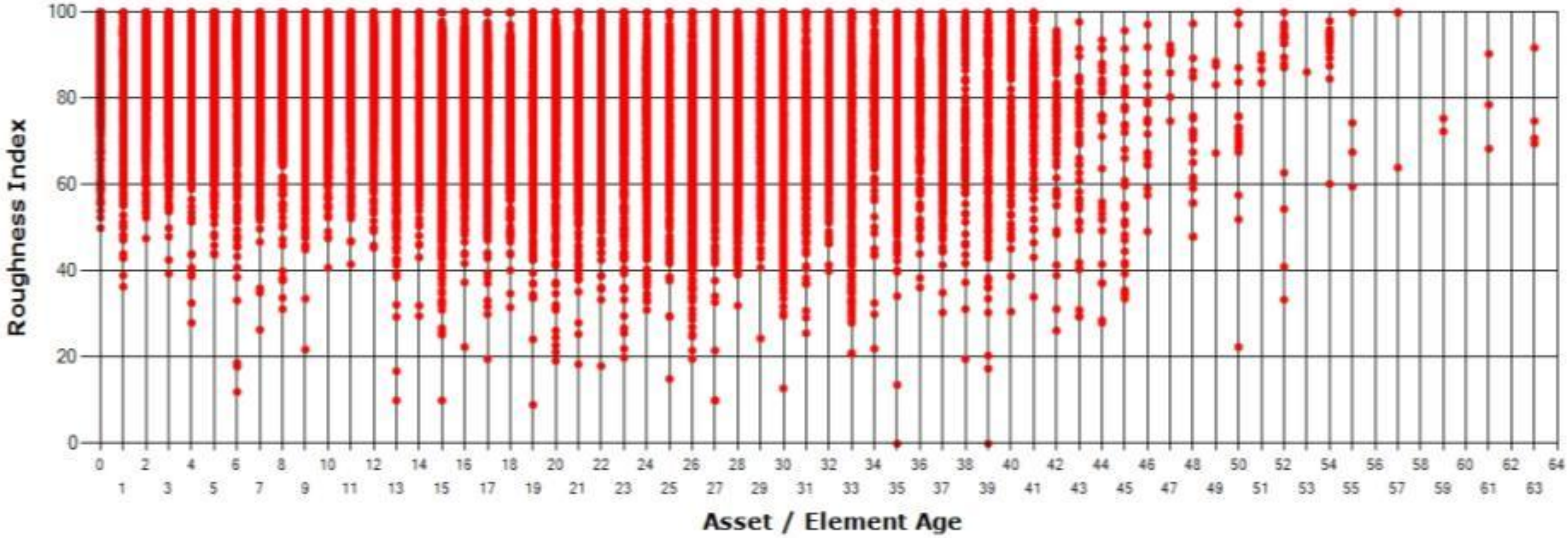
- Build a model out of this. I double dare you.

Using Field Data For Pavement Preservation

Data Preparation

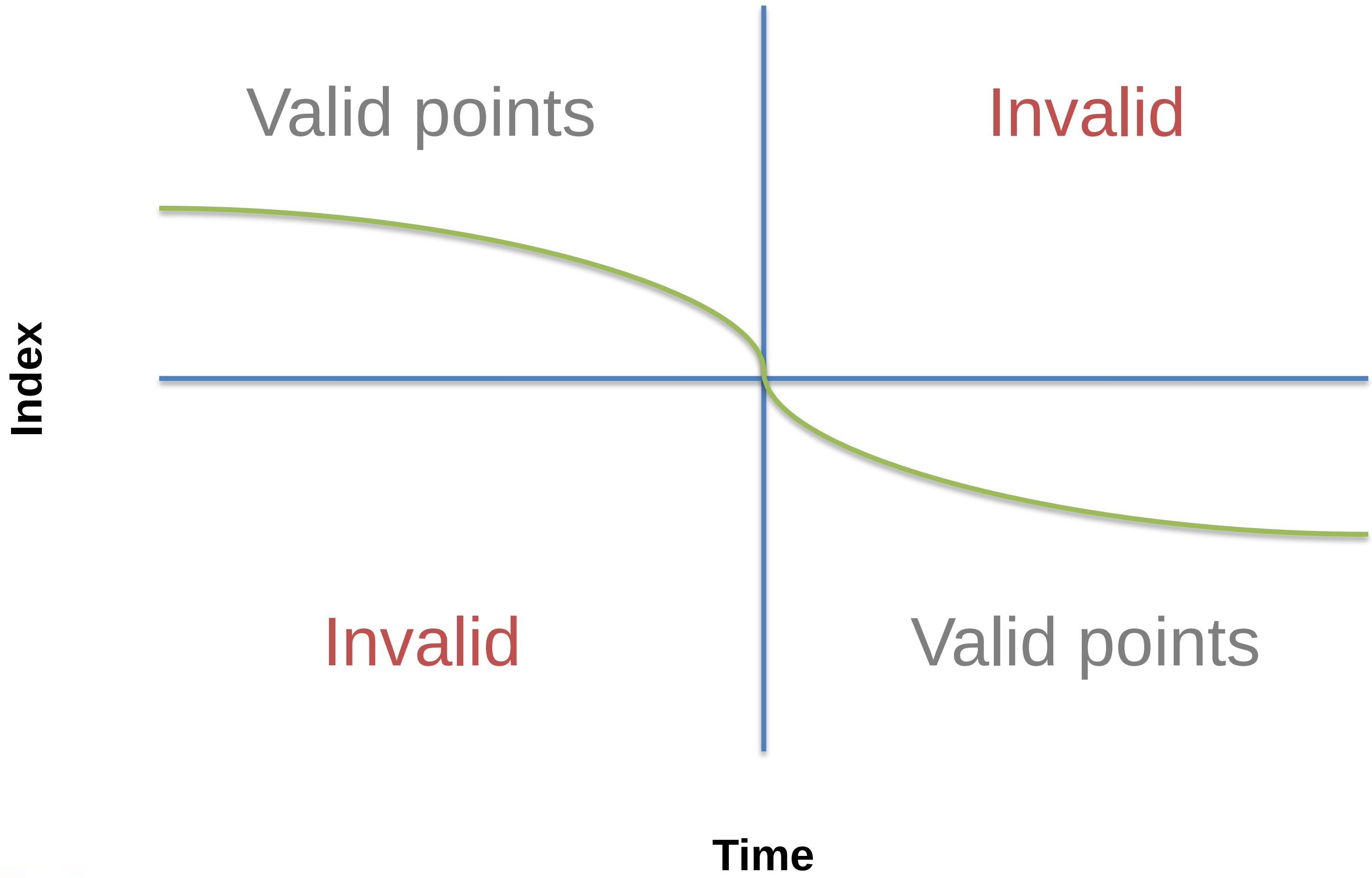


Data Preparation



- Every Roughness data point for a given roadway class (Composite Major Collector) in a network.

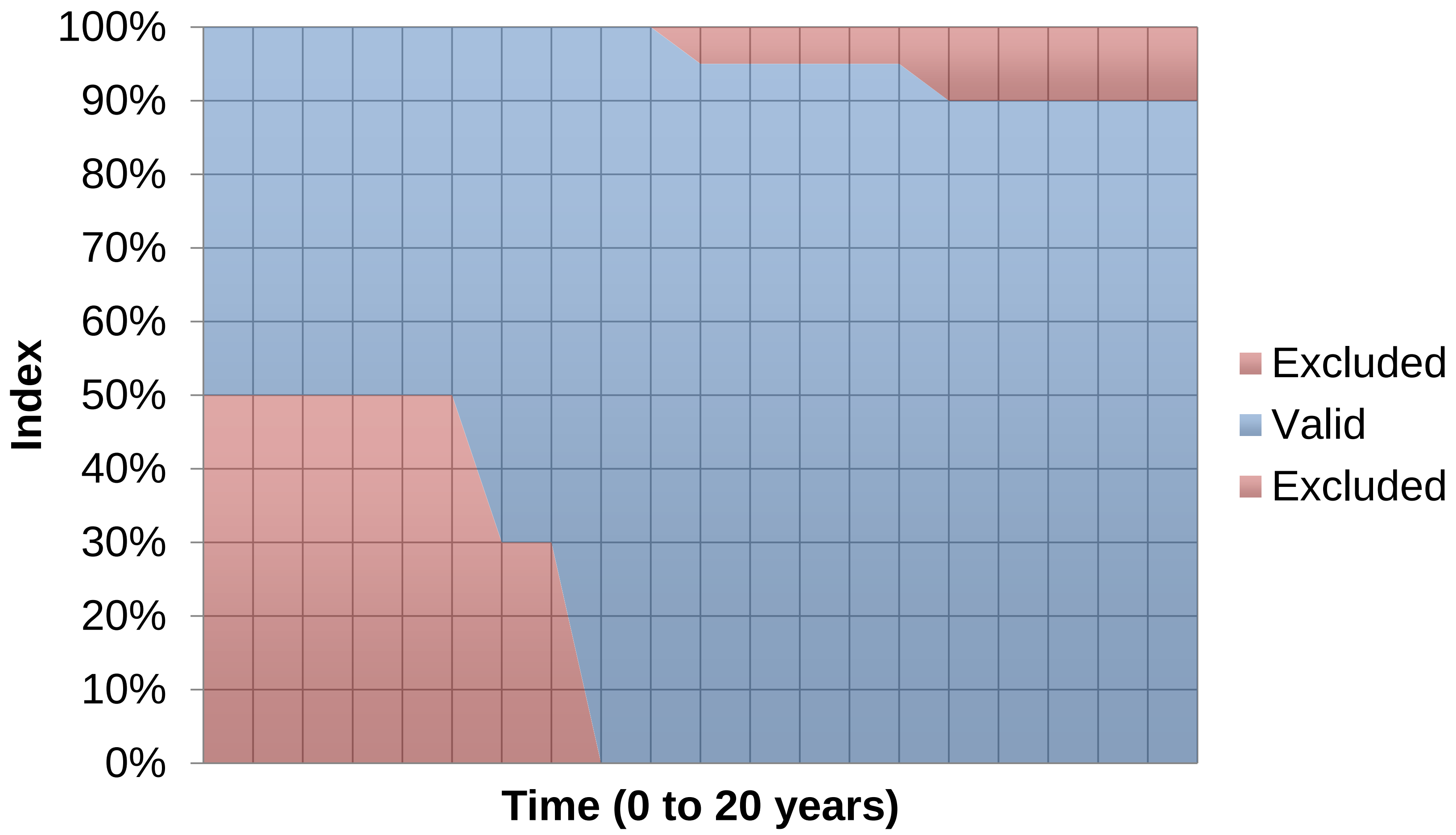
Data Preparation



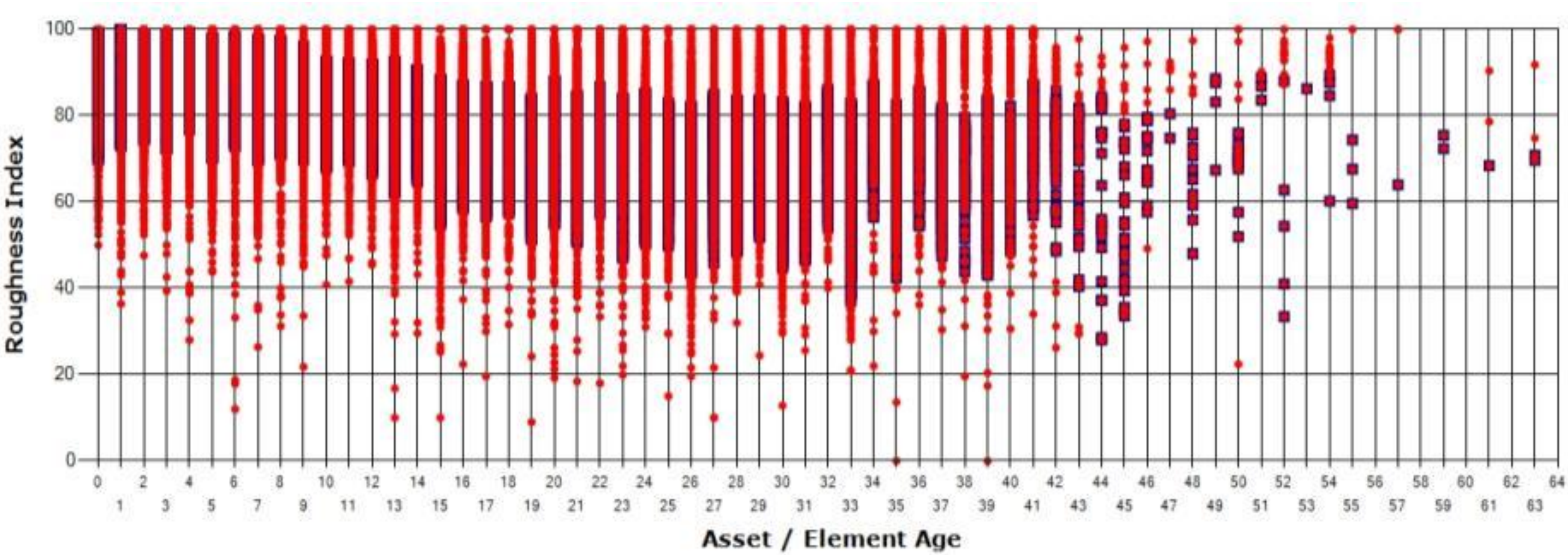
Data Preparation

- Data Exclusion Rules
  - Age < 5, Index < 50
  - Age < 7, Index < 30
  - Age > 10, Index > 95
  - Age > 15, Index > 90
- Excludes data points that are considered to be outliers (invalid data)
  - Criteria is based on engineering judgement.
  - Don’t be embarrassed to use trial and error.

Data Preparation

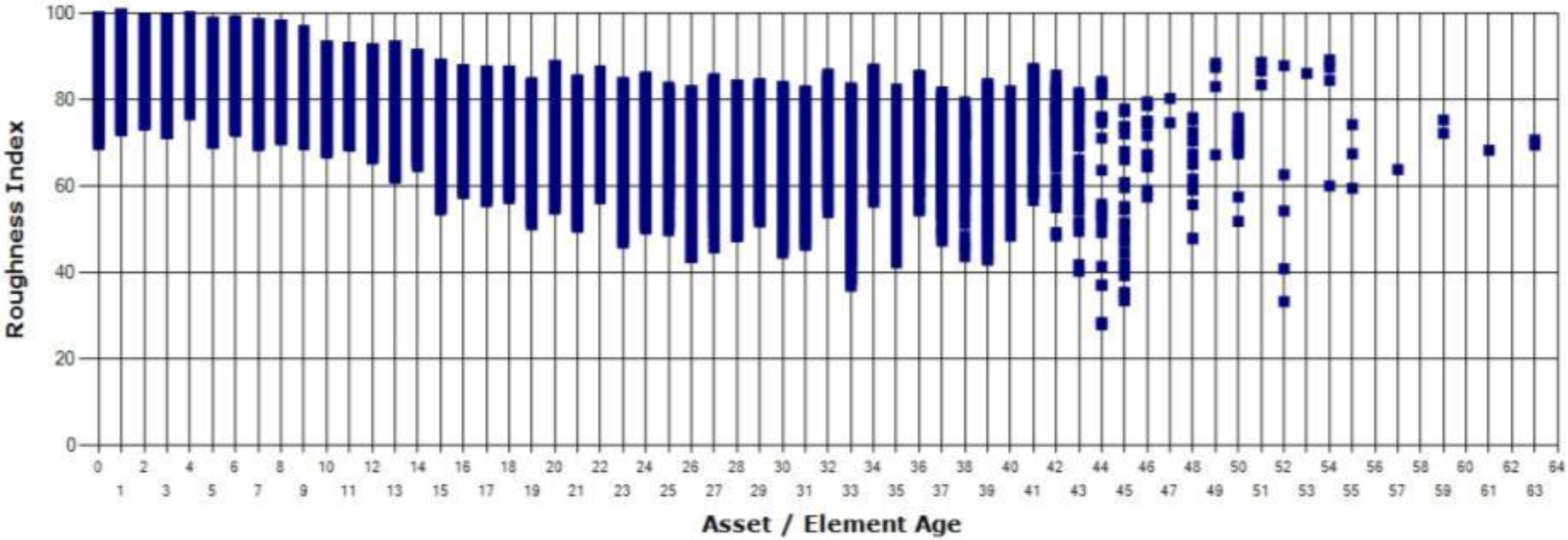


Data Preparation



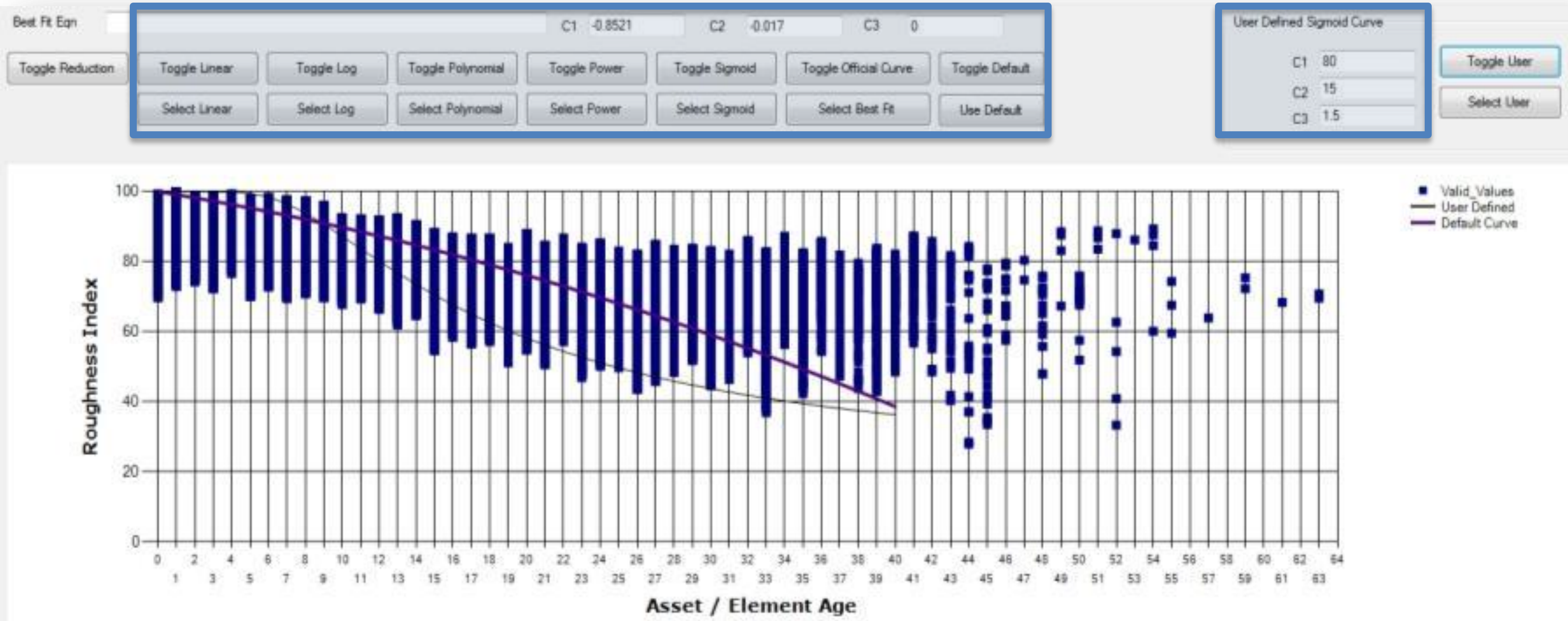
- Valid data points are highlighted in blue

Data Preparation



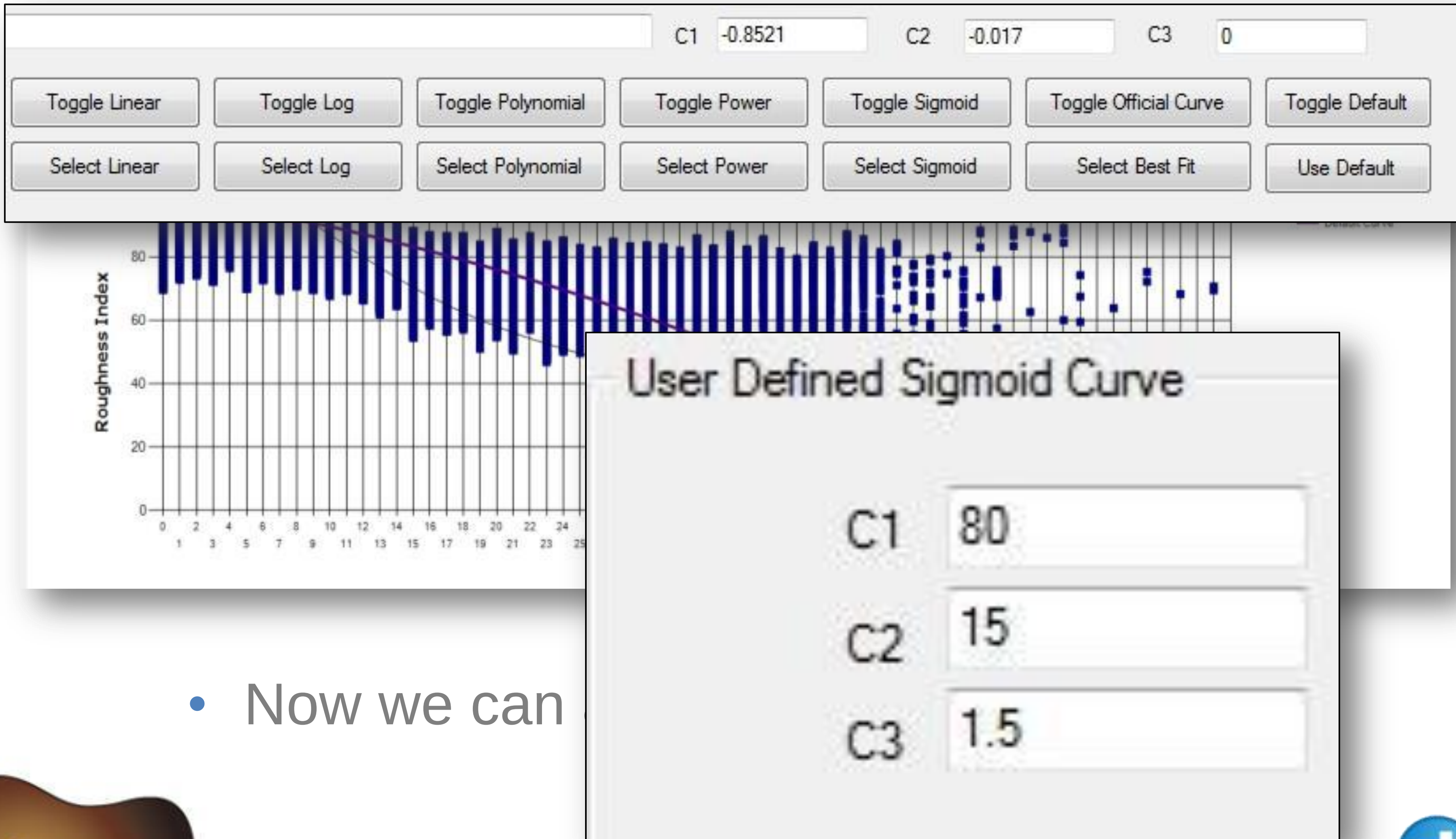
- Showing only valid data points

Data Preparation



- Now we can apply various curves

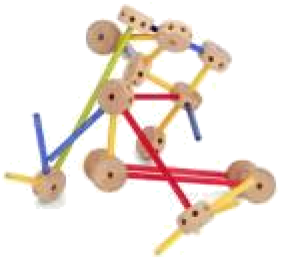
Data Preparation



- Now we can

Markov Transition Matrices

Probabilistic Modeling



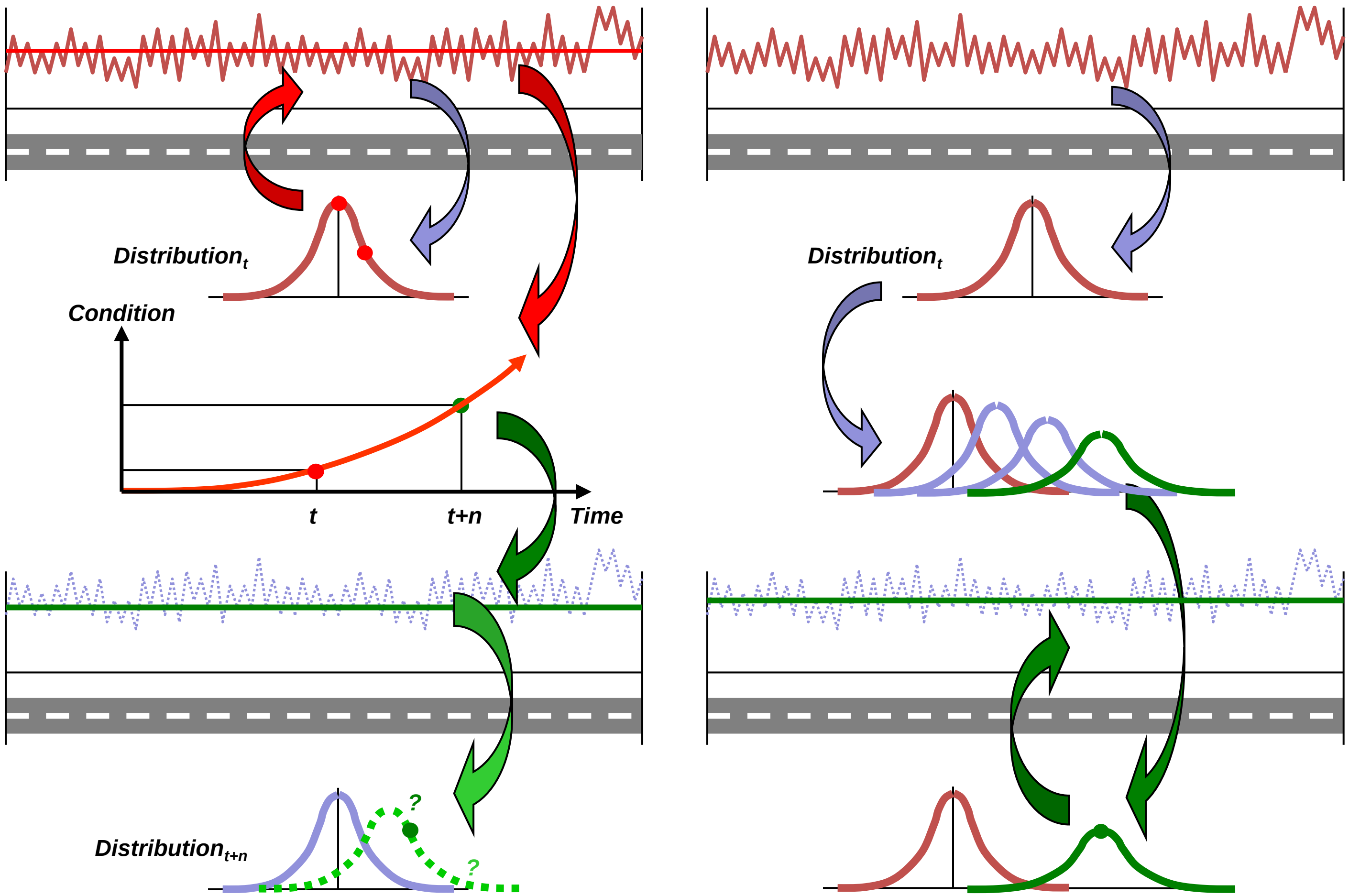
probability in an applied sense is a measure of the confidence a person has that a (random) event will occur.

(http://www.wikipedia.org)

Probabilistic Performance Prediction

Time „t“

Time „t+n“



Credit: Dr. Alfred Weninger-Vycudil, MSc., Ph.D.
PMS Consult, Vienna, Austria office@pms-consult.at

Probabilistic Performance Prediction

	Good	Fair	Poor
Good	0.80	0.00	0.00
Fair	0.20	0.70	0.00
Poor	0.00	0.30	1.00
Sum	1.0	1.0	1.0

X

t = 0
0.50
0.25
0.25
1.0

=

t = 1
0.40
0.28
0.33
1.0

3x3 Markov Transition Probability Matrix

Vectors describing condition states at t = 0 and t = 1

Credit: *Dr. Alfred Weninger-Vycudil, MSc., Ph.D.*
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10 x 10 Markov Transition Matrix

From/To	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%
100%	0.1421	0	0	0	0	0	0	0	0	0
90%	0.6130	0.5612	0	0	0	0	0	0	0	0
80%	0.2448	0.3825	0.6695	0	0	0	0	0	0	0
70%	0	0.0563	0.2886	0.7556	0	0	0	0	0	0
60%	0	0	0.0418	0.1770	0.9146	0	0	0	0	0
50%	0	0	0	0.0673	0.0416	0.9474	0	0	0	0
40%	0	0	0	0	0.0437	0.0332	0.9500	0	0	0
30%	0	0	0	0	0	0.0194	0.0288	0.9500	0	0
20%	0	0	0	0	0	0	0.0212	0.0261	0.5000	0
10%	0	0	0	0	0	0	0	0.0239	0.5000	1.0000
Sum	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**	**1.000**

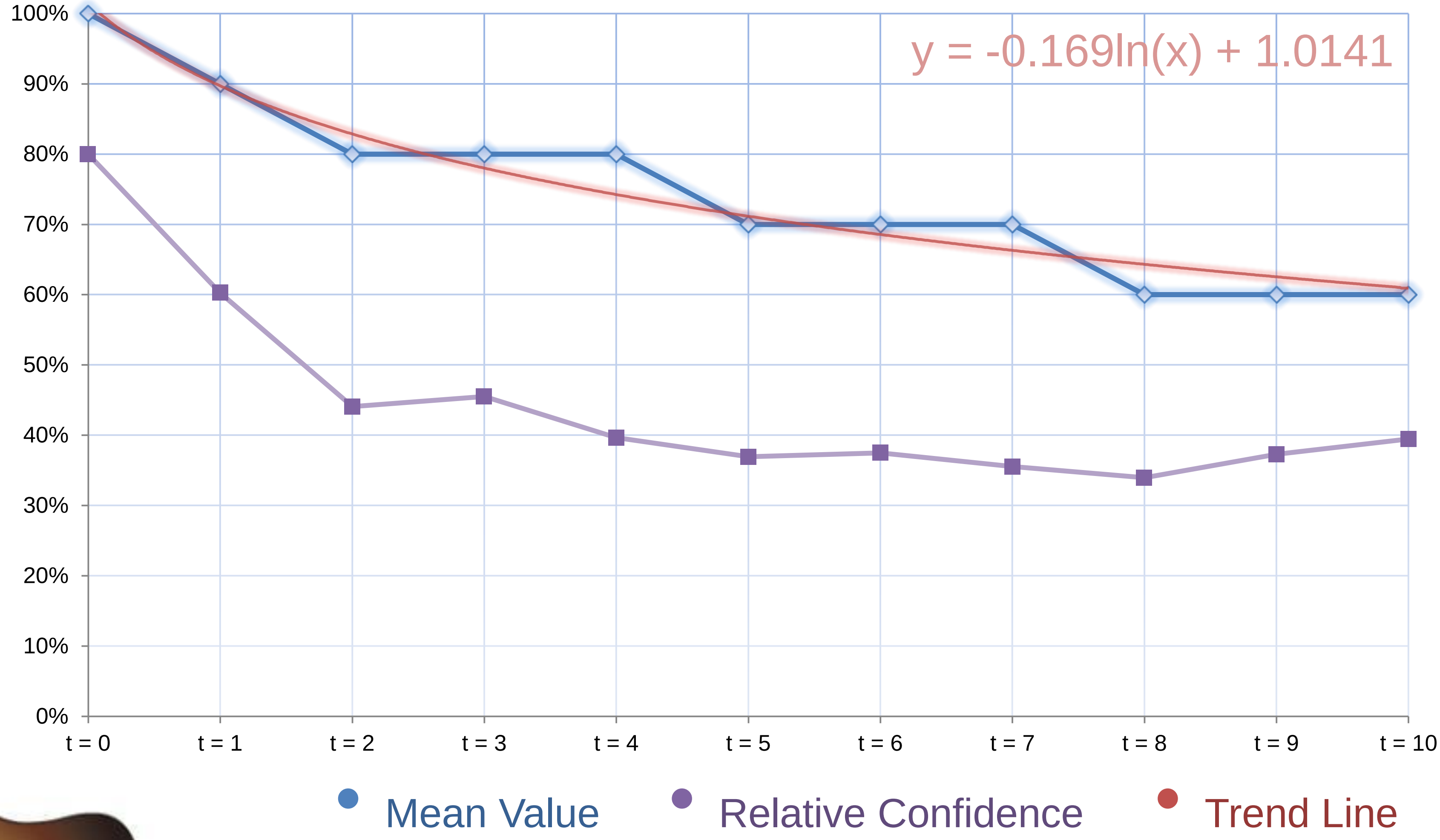
Low Traffic composite pavement after 2.5 to 3 inch overlay & surface treatment

Credit: *Dr. John R. Mbwana, Ph.D.*
Cornell University jrm15@cornell.edu

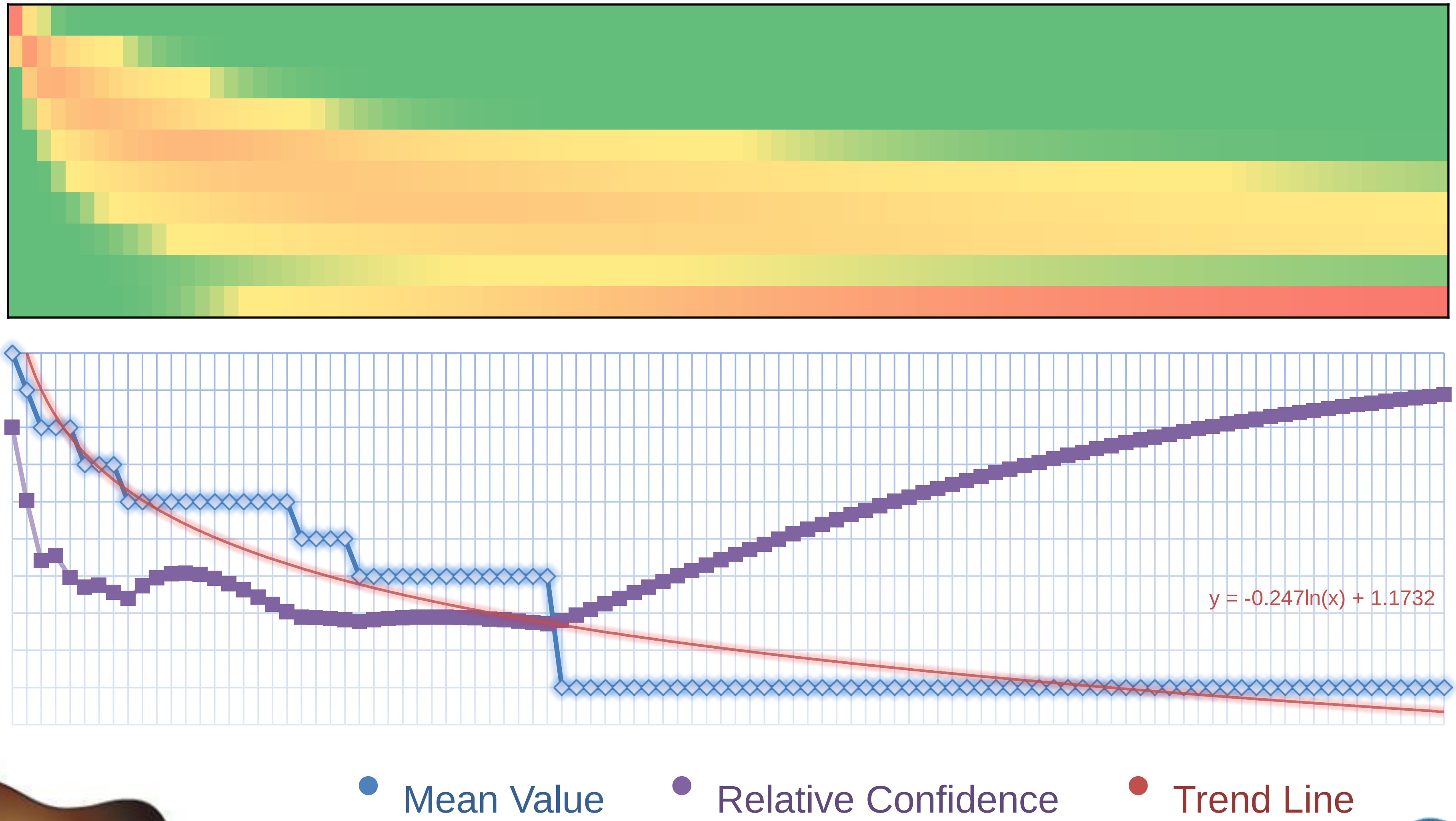
Resulting Probability Distribution

	t = 0	t = 1	t = 2	t = 3	t = 4	t = 5	t = 6	t = 7	t = 8	t = 9	t = 10
100%	**80%**	11%	2%	0%	0%	0%	0%	0%	0%	0%	0%
90%	**20%**	60%	41%	24%	14%	8%	4%	2%	1%	1%	0%
80%	**0%**	27%	44%	46%	40%	32%	24%	18%	13%	9%	6%
70%	**0%**	1%	12%	24%	33%	37%	37%	36%	32%	28%	24%
60%	**0%**	0%	1%	5%	11%	17%	24%	29%	34%	37%	39%
50%	**0%**	0%	0%	1%	3%	5%	8%	11%	14%	17%	20%
40%	**0%**	0%	0%	0%	0%	1%	2%	3%	4%	6%	8%
30%	**0%**	0%	0%	0%	0%	0%	0%	0%	1%	1%	2%
20%	**0%**	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
10%	**0%**	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
	100%	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Mean Value Confidence Plot /w Trend



100 Year Analysis (just for kicks)



How to Apply this to a COTS AMS?

- Store vectors rather than values for states.
  - Define value arrays in the system; the index of which identifies a state class.
- Enter matrices into the system rather than functions.
  - If your PMS does not inherently permit this, utilize external data functionality to point the PMS to matrices stored externally. (Excel is your friend here)

Probabilistic Modeling Benefits

- This type of modeling enables:
  - Accurately reflect uncertainty in values
  - Non-discriminately model different assets including bridges, culverts, guardrails, lighting, signs, etc.
  - Condition states are the most common application, but one can also consider congestion increase, level of service variations and even the risk and various consequence of failure.
  - Calculate different representative values (mean, median, standard deviation, percentiles, etc.)

Probabilistic Modeling Benefits

- Is working with scalar values unreal?
  - Probabilistic modeling may be considered more real.
  - Is this type of modeling more difficult or easier than traditional deterministic? Maybe a hybrid approach…
  - Developing transition matrices is no different than developing deterministic models. You need data, however the probabilistic method allows one to quantify their confidence (or lack of) in their data.
  - Deterministic or probabilistic, the models must be revisited and refined regularly!

Treat Your Models Well

Revisit and improve your models routinely. Models that lack regular attention may deliver an unexpected response…

Thank you for staying awake! *Arif Rafiq, B.A.Sc..*
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