IPAT

"Iowa Pavement Analysis Technique"

A concept for single segment and systemic evaluation of paved roadways

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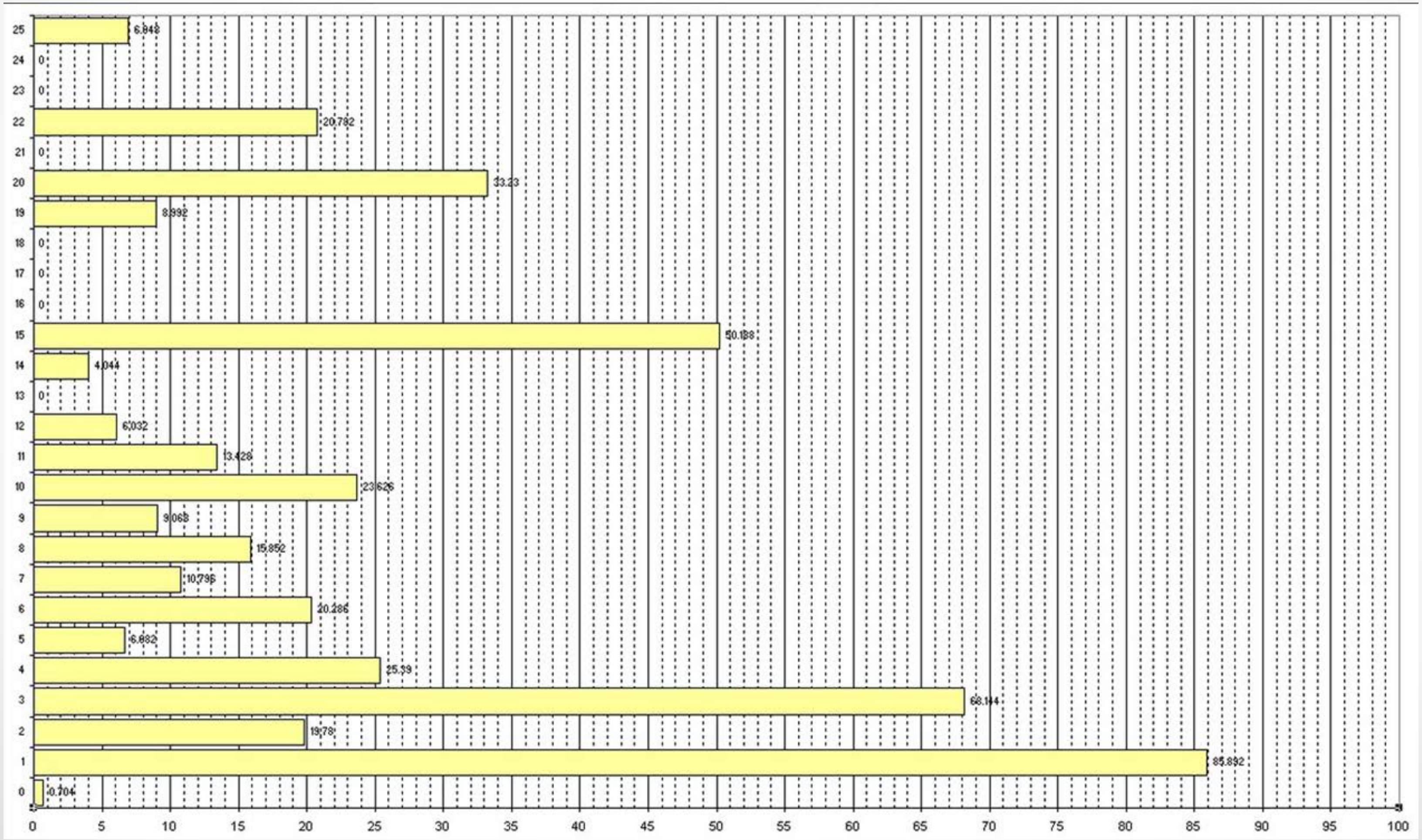
*IPAT Origins . . .

- Ongoing need to answer key questions:
  - Segment Level: What is today's condition, what's the target, when to we get there? What options are available?
  - Network Level: What is overall status? What is the trend? What needs to be done when?
- Need to communicate pavement issues to the public:
  - Calls for simple, easy to understand representations: RSL – mile years
  - Need a way to assemble statewide summary
- Desire to consume condition data from all sources
  - Automatic Distress Data Collection, Field CPI determinations, direct observation and analysis, IRI, FWD all produce useful data.
  - Ability to integrate all assessments would achieve best possible prediction of future condition trajectories
- FHWA and DOT asset management initiatives
  - Participation in ITAM awakened counties to need for new tools
  - Wanting to fulfill the vision without diverting too much staff time to operating and maintaining a system.
- Desire to understand full pavement picture:
  - Distress data + structure + traffic + weathering

Sample RSL chart

- RSL – Remaining Service Life. Chart below illustrates goal: to be able to communicate status and need to public and elected officials.
- 250 mile system loses 250 mile-years of RSL annually
- Need target 'ideal' graph to shoot for.



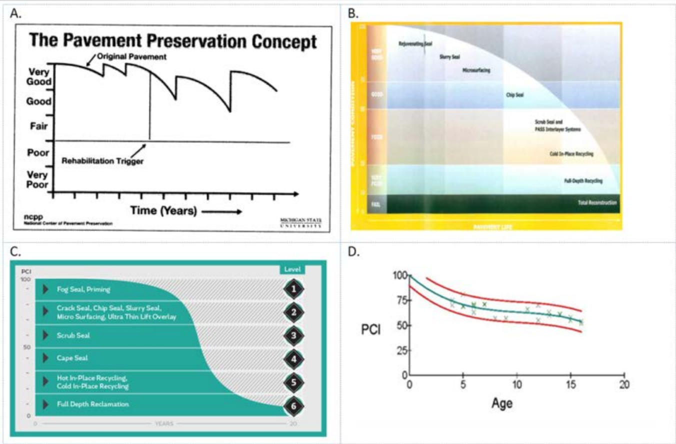
Sought an ‘all attributes’ analysis method:

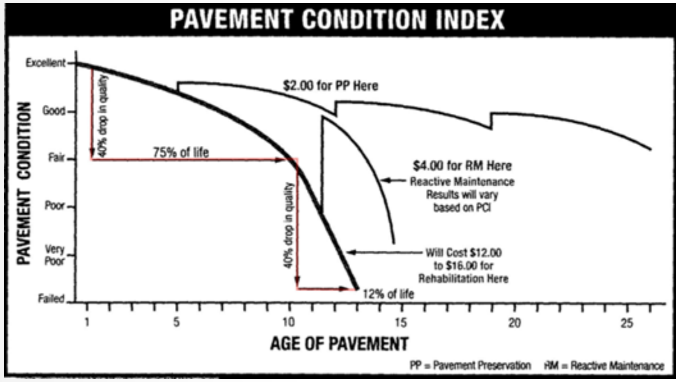
- Concluded the we need more than just surface condition to be able to predict future condition trends.
  - Two pavements of identical condition can have significantly different remaining lifetimes. Need to know additional things to have full picture:
    - Original ESAL capacity and design lifetime
      - Depends on layer ages, properties, depth in slab and prior wear
    - Impacts of both traffic (ESALs) and weathering/materials deterioration
      - Pavements wear out from both traffic and environmental factors
  - Tally of condition observations at points in time helps ‘see’ trajectory but can’t fully explain it.

ICEA's delegates to ITAM responded to the aforementioned issues by gradually synthesizing the IPAT concept

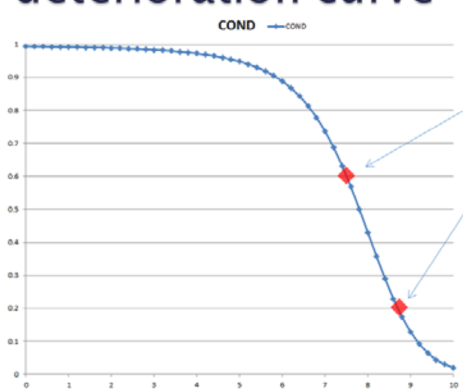
- Looked for a method that could:
  - Take into account distress date, traffic, materials, weathering
  - Be able to evaluate both from single segment and network perspectives
  - Enable access to data and analysis in both field and office
  - Be able to integrate data from any and all sources
  - Support progressively tuning model of any segment's life over time.
  - Have credible sophistication under the hood yet remain easy to understand on outside.
- Decided to try digitizing a pavement deterioration curve.

*IPAT synthesis





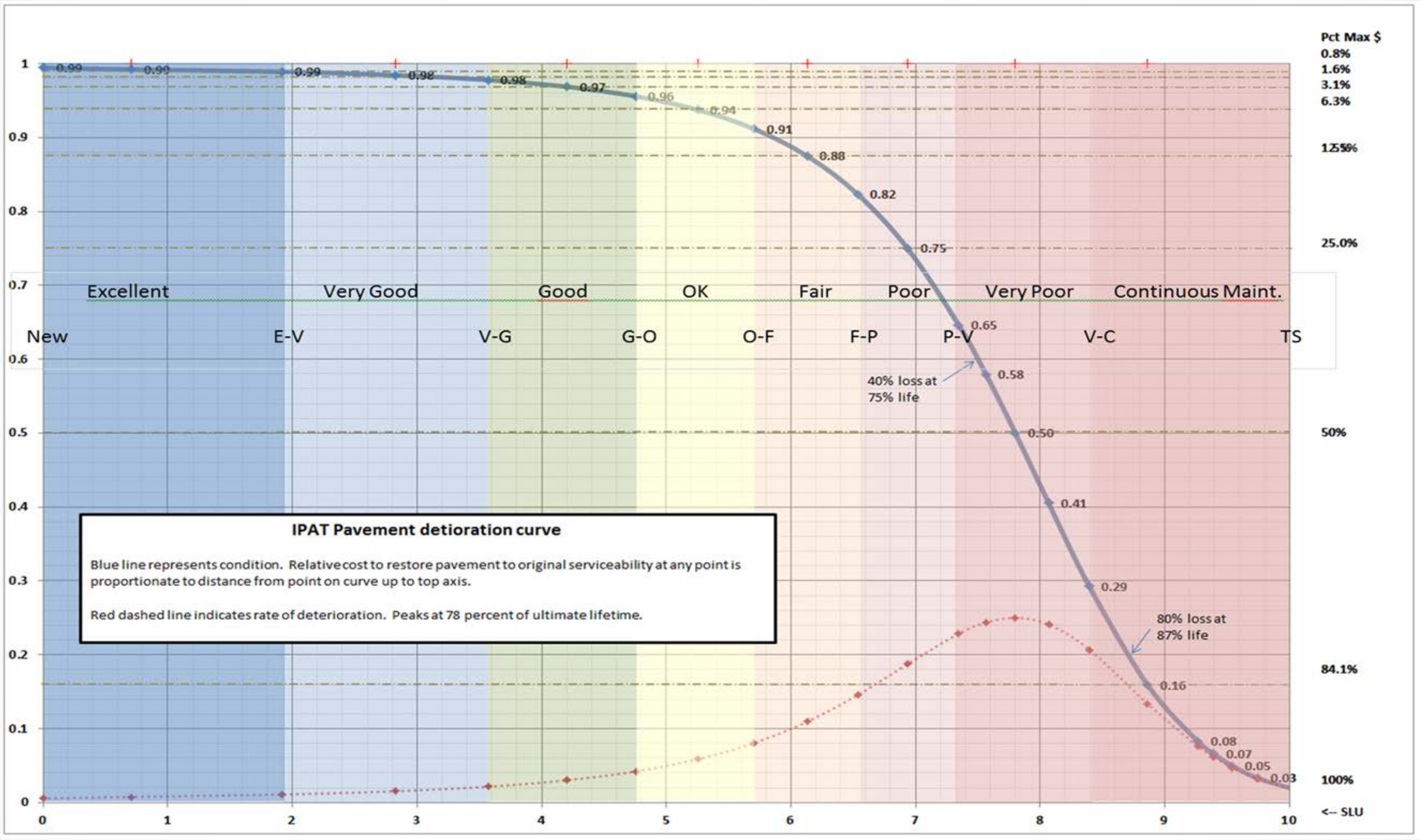
Synthetic, sigmoid based deterioration curve



- Curve fitting defined an inverse variant that passes through 0.6 at 7.5 and 0.8 at 8.7.
- What are the properties of the curve and how can it be used to represent condition at any stage of life?
- Note that it's non-dimensional and extends further down to the right than most other depictions.

- Looked at typical pavement deterioration curves
  - Qualitative representations
  - Not useful for analysis
- Decided to see if it would be possible to use mathematically defined curve
  - Did find undocumented assertion of 40% lost at 0.75 lifetime and 60% by 0.87
- Derived a formula and experimented with using it to model various pavement lifetime scenarios

IPAT curve properties



Non-dimensional, full life, variable deterioration rate, condition zones by powers of two

Modeling a segment’s lifetime

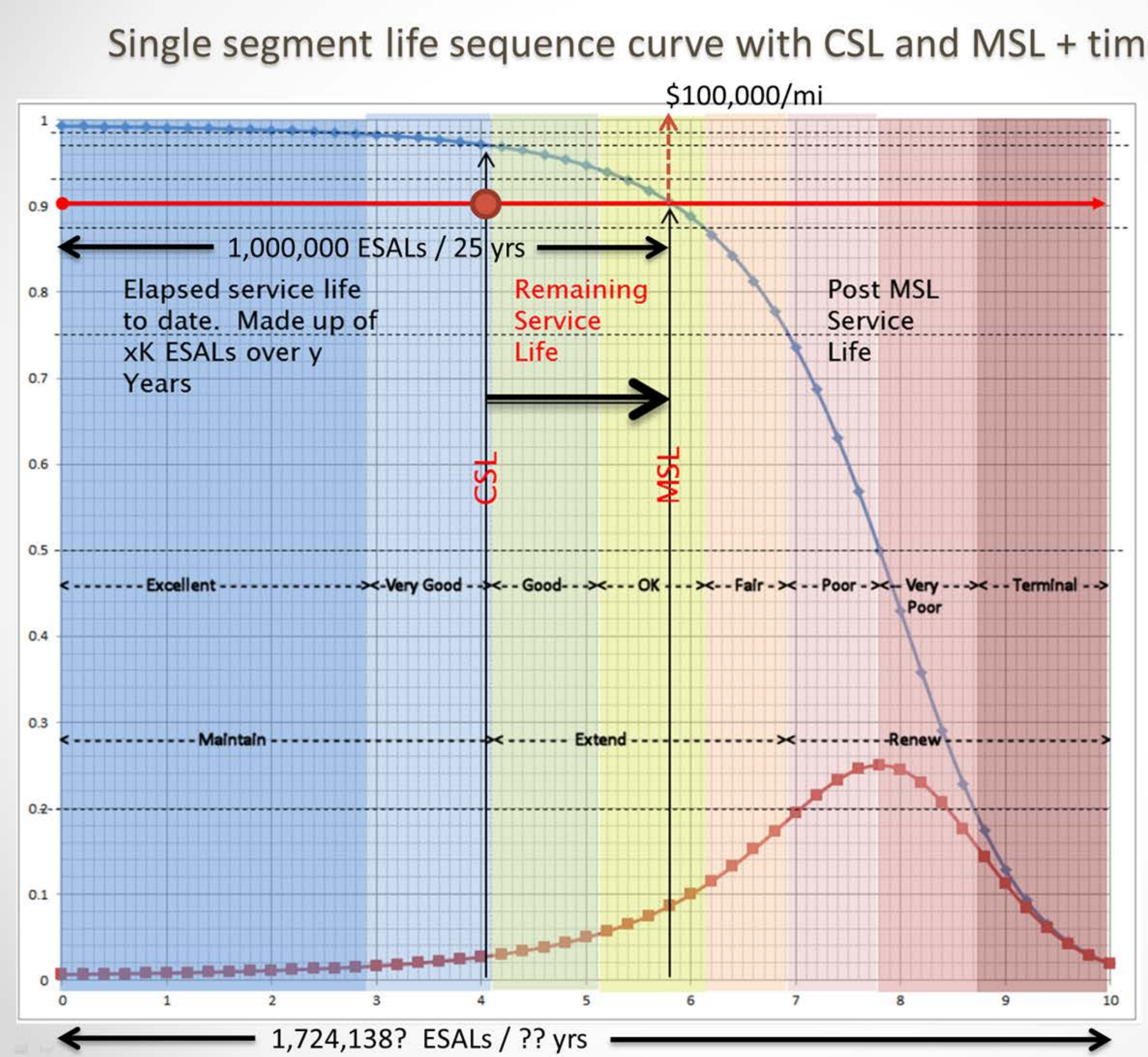


Figure out where things stand today: CSL

Establish the lowest condition level desired: MSL

Determine how many more ESALs it will take to arrive at MSL

Figure how many years it will take to establish “Est. Remaining Service Life’ or ERSL (non-linear)

Compare cost of acting today vs. cost of acting later.

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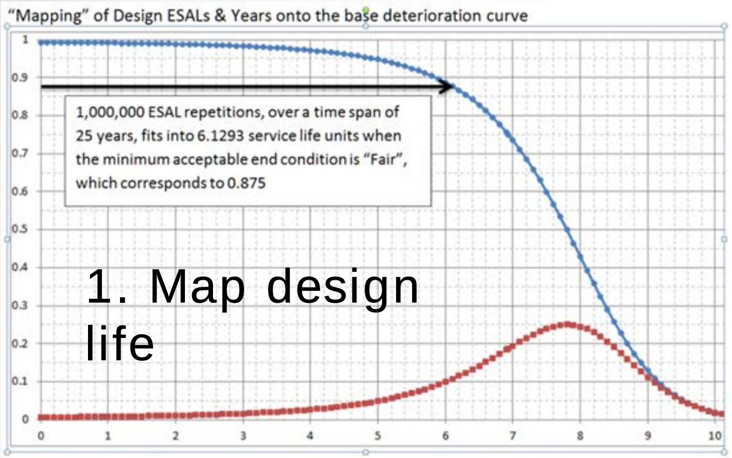
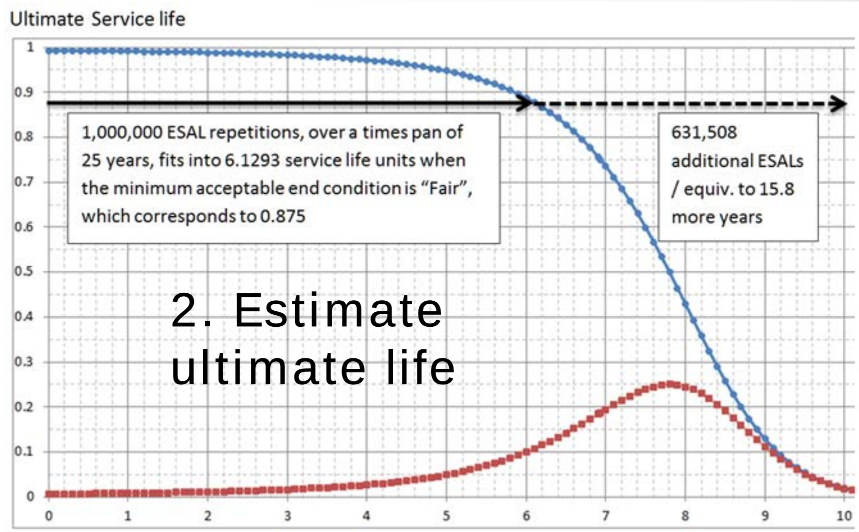
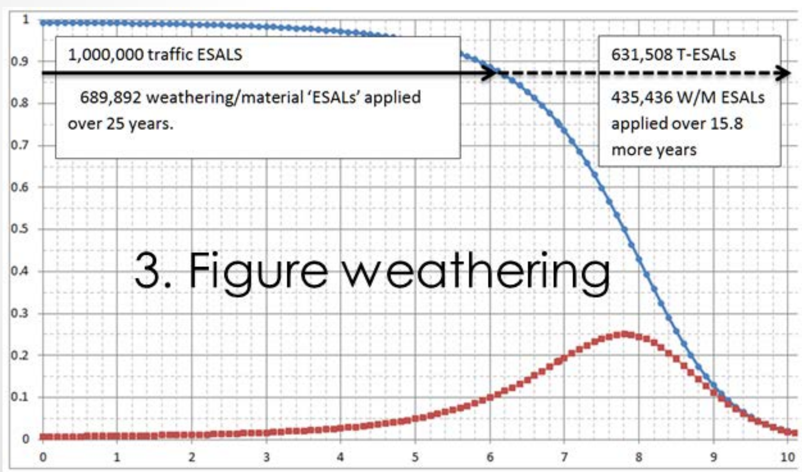
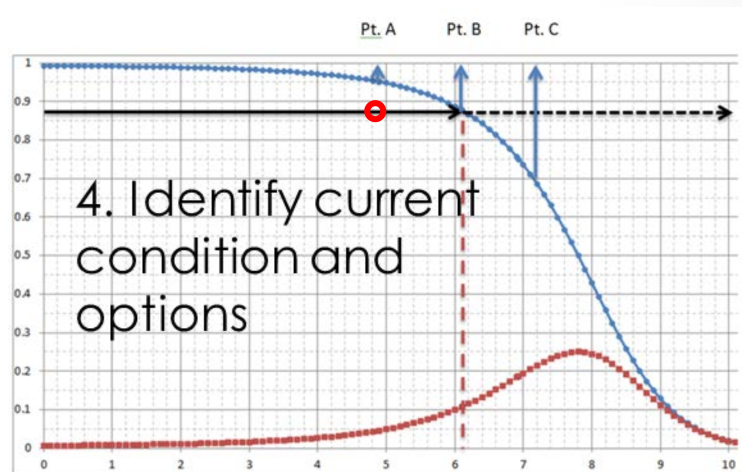
Single segment model process



IPAT presumes that the consumption of life units is linearly proportional to the cumulative total of ESAL impacts sustained. Thus the example shown above corresponds to 163,151 ESAL repetitions accumulating per SLU.







Weathering: 27,582 'ESALs'/yr or 100 Yr life w/o trucks

Field evaluation

- Spreadsheet IPAT curves where developed for various roads in 15 counties
- Did not find any life cycle / traffic / pavement structure combination that couldn’t be modeled.
- Spreadsheet version proved workable in the field
- Facilitated what if analysis of structural and pavement preservation treatments
- Enabled determination of Remaining Service Life
- Method did seem able to answer ‘key’ questions

Curve tuning

- Field testing demonstrated that IPAT could support successive refinement of any given segment's model, as new condition data becomes available.
- Decided to call it 'Curve tuning', since the goal is to optimize the fit of the curve to the reality in the field
- Works as follows:
  - get a number of data points
  - regress IPAT curve formula for best fit
  - repeat at each successive new observation.
  - Iteratively results in curve that most realistically represent future trajectory.
  - Tuning adjustments are made by varying key variables used in the model: initial ESALs, design life, traffic, weathering, etc.
  - Goal is formula that best predicts future trend.

*Pavement Structure Issues

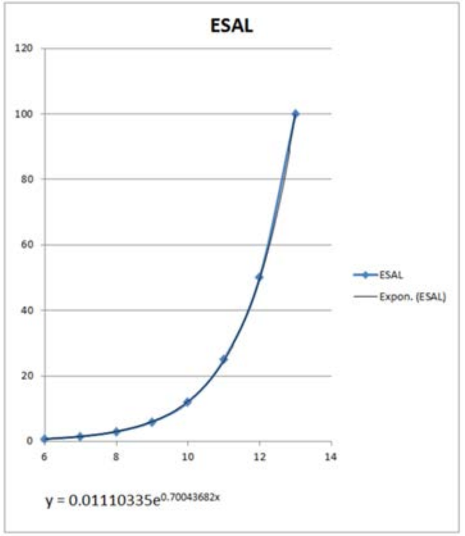
- As the IPAT exploration evolved, it became apparent that a reasonably good way of estimating ESAL capacity at the start of a pavement's service lifetime was needed.
  - Didn't need perfection, just order of magnitude to get started – since adjustments could come from tuning to fit observed conditions over time.
- So . . . began looking at pavement structure in more detail.
- Realized that in our modern 'preservation' era, people seldom build new pavements from scratch. More often they apply treatments and new lifts on top of a stack of pre-existing layers
  - Thus future performance also depends on past history, which can be complicated
- Also realized that saying a pavement has a capacity of X-ESALs over Y-years, carries an implicit "subject to prevailing weather conditions" assumption.

Trial structure concept

- Didn't need a perfect answer to be able to set up a curve and start tuning it - but still need to start somewhere. So initially chose to mimic Structural Number concept. *Service Value Index - SVI*

- Method: Assign age adjusted SVI's to each layer, sum them up and use total to compute an ESAL capacity.

- Discovered and used a roughly 5th power relationship between the SVI and life ESAL



ESAL estimate - sample case - Stage 2 - 2 inch HMA resurface at 15 years

YB	Layer	Thick	SVI fctr	Int. SVI	PSF	Final SVI	ESALs
2030	HMA surface	2.0	0.80	1.600	1.0	1.600	
2015	HMA surface	3.0	0.80	2.400	0.7	1.680	
2015	Type B base	6.0	0.50	3.000	0.8	2.400	
2014	Gran. Base	4.0	0.08	0.320	0.8	0.256	15 yr est life
		15.0		7.320		**5.936**	673,563

SVI calcs led to awareness of pavement complexity

- In a multi-layer pavement, each lift has a unique age, thickness, depth in slab, stress level, material, physical condition, modulus, and prior traffic carriage impacts.

- Began to realize that understanding composite behavior with simplistic Structural Number & prior service factors concept, plus an ESAL capacity vs. SN curve. might not be enough.

- ‘Discovered’ that Iowa Counties have a dispersed database of pavement histories from around the state.   Began wondering if this information could be gathered, digitized, and used to develop a predictive model.

Illustrative pavement history

Example portrays cumulative history of a pavement through five cycles of construction and renewal.

Thickness, age, depth in slab, prior ESALs, and prior F/T cycles change as time passes.

2017 update would need to serve as basis for estimating next design life and ESAL capacity going forward.

400 vpd (1960) @ 2%/yr / 9% trucks w/ 0.4% growth.

Year Const	Layer ID	Thickness	Age	Depth	CumESAL	F/T cycles
1960	Type B	2	0	0	0	0
1960	ATB	6	0	-2	0	0
1960	Granular base	4	0	-8	0	0
1960	Natural Subgrade CBR = ?	**12**			0	0
1975	Type B	2	0	0	0	0
1960	Type B	2	15	**-2**	290954	1440
1960	ATB	6	15	-4	290954	1440
1960	Granular base	4	15	-10	290954	1440
1960	Natural Subgrade CBR = ?	**14**			290954	
1992	HMA	2	0	0	0	0
1975	Type B	2	17	-2	425761	1632
1960	Type B	2	32	-4	716715	3072
1960	ATB	6	32	-6	716715	3072
1960	Granular base	4	32	-12	716715	3072
1960	Natural Subgrade CBR = ?	**16**			716715	
2005	HMA	1.5	0	0	0	0
2005	CIPR	4	0	-1.5	0	0
1960	Type B	2	45	-5.5	1248296	4320
1960	ATB	6	45	-7.5	1248296	4320
1960	Granular base	4	45	-13.5	1248296	4320
1960	Natural Subgrade CBR = ?	**17.5**			1248296	
2017	HMA	3	0	0	0	0
2005	CIPR	2.5	12	-3	620056	1152
1960	Type B	2	57	-5.5	1868352	5472
1960	ATB	6	57	-7.5	1868352	5472
1960	Granular base	4	57	-13.5	1868352	5472
1960	Natural Subgrade CBR = ?	**17.5**			1868352	

*IPAT Research project

- Conducted field evaluations of concept efficacy and robustness during summer of 2015
  - Contacted county engineers found the methods reasonably credible
  - Found that all circumstances found in the field can be modeled
  - Learned of desire to predict value/duration of pavement preservations
  - Determined model could work on both segment and network levels
  - Discovered the treasure trove of pavement histories on file

- Discussed and refine the ideas at LTAM meetings

- Feb 2016 – presented to CERFG and received good score

- Feb 2017 – Submitted Problem statement to IHRB. Rated as a top priority to become eligible for RFP and formal research proposal

- Now seeking research partner(s)

IPAT research goals

- 1. Find the best tecnology to mathematically define deterioration curves and identify how to tune them.
  - Is the logistics curve the best fit or should curves be synthesized some other way?
  - What would be the best way to combine condition observations from disparate sources and use them collectively to tune the model?
  - Can we validate that starting ESALs, design lifetime, traffic, weathering, and subgrade are the exclusive essential variables?
  - Can tuning be automated?

- 2. Develop method(s) to better analyze and predict lifetime ESALs of multi-layered pavements
  - Collect and digitize the counties’ dispersed pavement data?
  - Can we analyze it in a fashion that will help build a reliable lifetime and ESALs predictor for the future?
  - Can we build in MEPDG methods and prior research?

Engineering practice goals

- Level 1 - Be able to define and tune segment by segment curves as a basis of pavement condition analysis and tracking.
- Level 2 - Have an ability to analyze existing and predict future multi-layer pavements' ESAL capacity, service life and weathering characteristics
- Level 3 - Be able to analyze mid-life impacts/actions: change in VPD, Detours, Pavement preservation, etc
- Level 4 - Support each county being able to report the RSL of their system in terms of miles of road at each RSL level. Support consolidation of this information at the statewide level.

Implementation goals

- Initial curve and pavement layer implementation by spreadsheet.
- ICEASB to follow up with building an app that would enable counties to use the curve model to track and predict pavement performance:
  - County would map out ‘uniform project sections’ via an online interface.
  - A model would be set up for each section
  - Models would be tuned, revised, and reset over time as data comes in.
  - Results would be consolidated to show Miles x RSL, at both county and statewide levels
  - Parallel app would assist with multi-layered pavements analysis
- ICEASB would provide mobile version of app to enable engineers to access data on and reevaluate pavements while observing them in the field.
- Over time, the collected condition model and pavement structure data would become a research resource of its own.

*Possible mobile app

Poweshiek County, IA	List of pavement segments 45 count (257.340 mi)			4/14 2014
Route	**Miles / AADT**	**Crnt Status**	**Tgt MSL**	**MSL Yr**
M-17	3.692 (652)	VG/G	OK/F	2019
	From US 7 to WCL Anyoldtown			
G-45	12.365 (450)	VG	F	2022
H-15	12.125 (1000	G	F	2021
B-12	0.56 (85)	F	P/VP	2028
B-22	1.512 (360)	P	F/P	x2012
C-10	6.412 (3500)	E	OK/F	2035
H5B	3.984 (180)	G/O	F	2020
J-20	15.420 (1250)	G	F	2017

Map	P-Structure	Notes	Photos	List
Sgmt Info	History	Files	Eval. info	LCA

Poweshiek County, IA	M-17 [A]	3.692 mi	24 ft x 2 lane	4/14 2014
	From US 7 to WCL Anyoldtown			
Pavment HMA	Built/Rebuilt	1998		
	Max. life	80 yrs		
	Min. Svc. Lvl	Ok/Fair		
Traffic	AADT	650	10.2% Trks	
	Exp. Factors	0.9985 / yr	1.005 / yr	
	ESAL use		1.15 / trk	

Life Cycle Analysis	ERSL = 7 yrs		[AADT]	[IRI]
New/Redone	1998		664	14
Excellent	2003		660	20
Very Good	2009		654	30
		◄CSL (2012)		
Good	2014		650	~50
OK	2018		646	~100
		◄MSL (2019)		
Fair	2021		641	~175
Poor	2024		638	~250
Very Poor	2027		636	~350
Terminal	2033		630	~500

Map	P-Structure	Notes	Photos	List
Sgmt Info	History	Files	Eval. info	LCA

Questions? Ideas?