Use of Expert Judgment in Risk Assessments Involving Complex State Spaces

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MOTIVATION

- Detailed inspections of in-service wiring show that problems are common to both large and small transport aircraft:
  - inadvertent damage during maintenance, such as using wire bundles as ladder rungs, stepping on and damaging wiring hidden under insulation blankets,
  - inadequate support clamping,
  - improper installation that can aggravate chafing
- Today's jet aircraft rely more and more on sophisticated electrical and computer systems, placing a premium on the reliability of wiring, power feeder cables, connectors and circuit protection devices.

MOTIVATION

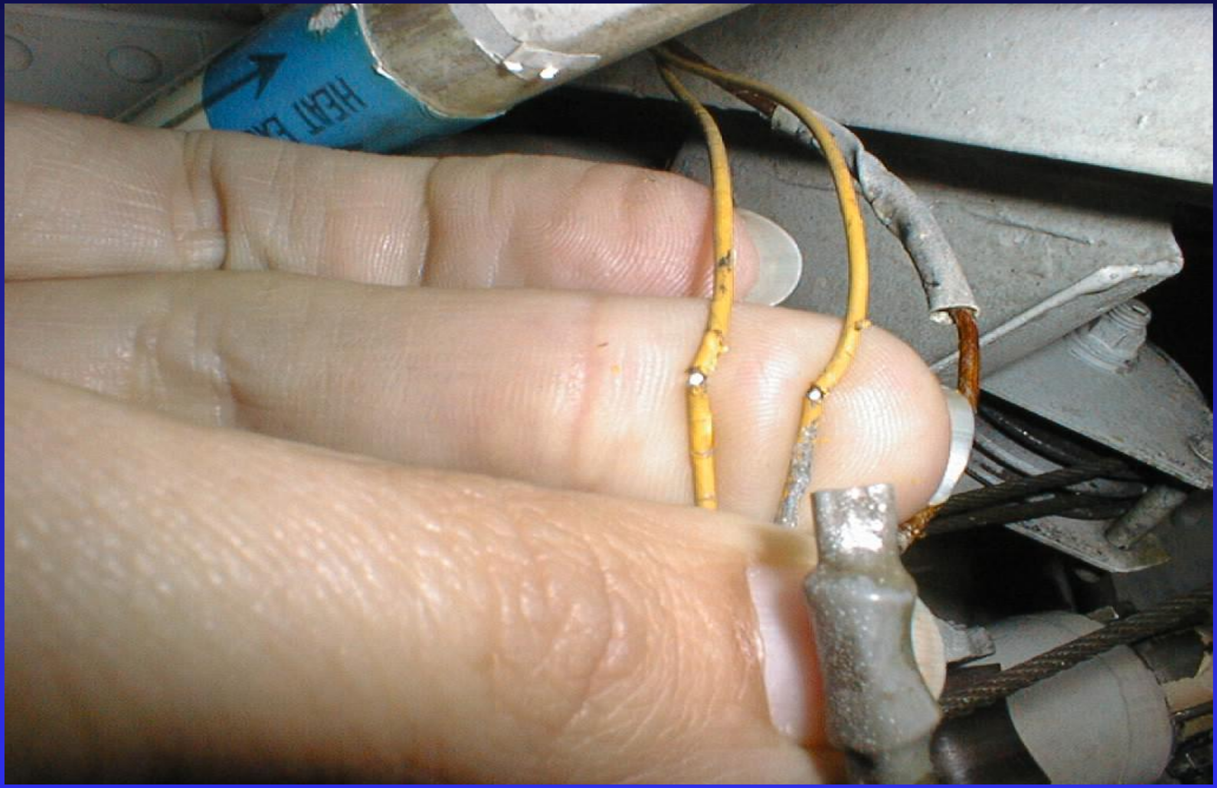
- The physical failure of wiring has
  - caused damage to other aircraft systems
  - ignited flammable material in close proximity to wiring.
  - caused malfunctions that have contributed to turnbacks and in-flight diversions
- The amount of wiring in transport category aircraft has grown steadily over time, with no plateau yet visible. The more of it, the greater the potential exposure to wiring failures.

MOTIVATION

"The increasing reliance on electrical power on modern and future public transport aircraft for flying control, engine and flight management systems with the associated increase in the use of computers, in addition to passenger services and entertainment systems, makes such aircraft more vulnerable to electrical fires and their potential effects, particularly if the flight crew do not receive timely warnings of electrical fire initiation."
(Investigative report United B767-300 on a Jan. 9, 1998, the UK's Air Accidents Investigation Branch)

Wires failures events can occur at three levels

Wire Level

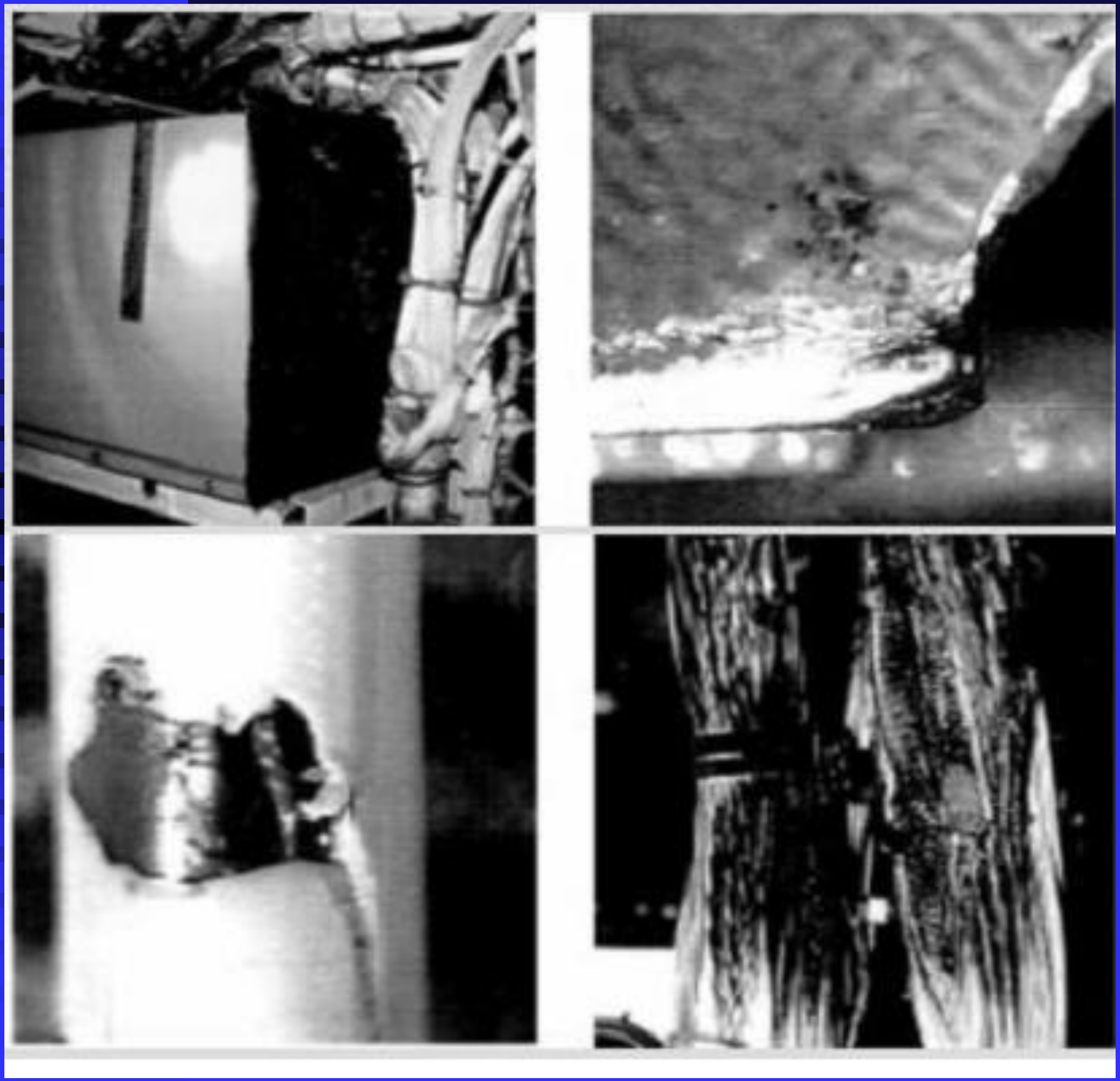


Insulation has faults. An EWIS failure probably has not occurred yet but the probability of an EWIS event is much higher. A common cause fault is indicated as the breach in the insulation line up.

Bundle Level

An arcing event has occurred. It is assumed that the arcing event began with one or two wire chaffing against the standoff. However, as a result of the arcing many wires in the bundle have failed. The possible effect of the failure depend on which systems are routed in the bundle.

Zonal Level



Upper Left: Install chiller in EE bay. Large object in a zone with high wire density.

Upper Right: Rough metal edge of cooler.

Lower Left: Chafed wire.

Lower right: Resulting arcing in two adjacent bundles.

United Airlines B767-300, Jan. 9, 1998

DEVELOPEMT OF WIRE FAILURE MODEL

- Failure Modes
  - Opens: "fail to open"
  - Shorts: "fail to ground"

- Failure Density

  $f(t_i|\lambda_i) = \lambda_i \exp\{-\lambda_i t_i\}$ where i=o, g

- Time until wire failure

  $T = \mathrm{Min}\{T_o, T_g\} \sim \exp(\lambda_o + \lambda_g)$

- To completely specify the distribution, this parameter must be estimated, usually from past data

INCORPORATION OF ENVIRONMENTAL VARIABLES

- But there are many types of wiring environments and these environments will affect the failure rates
- A common model for incorporating the affect of covariates is the proportional hazards model (PHM)
- The basic idea of the model is to write the failure rate as a function of the covariates $X_1, \ldots, X_n$

$$f(t|\beta_0, \beta_1, \ldots, \beta_n) = [\exp\{\beta_0+\Sigma_{j=1,n}\, \beta_j X_j\}]\, \exp\{ -[\exp\{\beta_0+\Sigma_{j=1,n}\, \beta_j X_j]t \}$$

where β_0 is some base failure rate and β_i reflects the influence of X_i on the failure rate

- but not much failure data exists except for a few wire types

EXPERT JUDGEMENT USING PAIRED COMPARISON

- Paired Comparison
  - Designed to measure group preferences for a set of objects by letting subjects judge the objects 2 at a time
    - for each pair of objects, each subject simply states which of the 2 objects (s)he prefers
  - Allows for statistical tests for
    - individual expert responses
    - expert responses as a group
- Models for paired comparison
  - Thurstone (1927)
  - (Bradley and Terry, 1953)
    - These models also provide goodness of fit tests

OVERVIEW
PAIRED COMPARISON

- Set up
  - Let $E_1, \ldots, E_n$ denote the objects to compare
  - e experts are asked a series (specifically a total of n taken 2 at a time) of paired comparisons as to which they prefer – the idea is that comparing items two at a time is easier than comparing items all at once
  - Let $N_r(i)$ represent the number of times that expert r preferred E_i to any other
  - The paired comparison results yield values $N_r(1), \ldots, N_r(n)$ for each expert $r = 1, \ldots, e$.

OVERVIEW
PAIRED COMPARISON

- Testing if each expert is specifying a true preference structure in his/her answers or just assigning answers in a random fashion.
  - This can be determined by analyzing the number of circular triads in his/her comparisons.

    $E_1 > E_2$, $E_2 > E_3$, and $E_3 > E_1$
  - David (1963) determined that *c(r)*, the number of circular triads in expert r's preferences, is given by

$$c(r) = \frac{n(n^2-1)}{24} - \frac{1}{2}\sum_{i=1}^{n}\left(N_r(i) - \frac{1}{2}(n-1)\right)^2$$

OVERVIEW
PAIRED COMPARISON

- Kendall (1962) developed tables of the probability that certain values of ***c(r)*** are exceeded under the null hypothesis that the expert answered in a random fashion for n = 2, …, 10.
- In addition, Kendall (1962) developed the following statistic for comparing n>7 items

$$c'(r) = \frac{n(n-1)(n-2)}{(n-4)^2} + \left(\frac{8}{n-1}\right)\left[\left(\frac{1}{4}\right)\binom{n}{3} - c(r) + \frac{1}{2}\right]$$

- The above is chi squared with n(n-1)/(n+2) df
- Expert eliminated if we the random preference hypothesis cannot be rejected at the 5% level of significance

OVERVIEW
PAIRED COMPARISON

- The agreement of the experts as a group can be statistically validated. Let ***N(i,j)*** denote the number of times some expert preferred E_i to E_j.
- To test the hypothesis that all agreements of experts are due to chance, Kendall (1962) defines the *coefficient of agreement* as

$$u = \frac{2\sum_{i=1}^{n} \sum_{j=1, j\neq i}^{n} \binom{N(i,j)}{2}}{\binom{e}{2}\binom{n}{2}} - 1$$

OVERVIEW
PAIRED COMPARISON

- Kendall tabulated distributions of $$\sum_{i=1}^{n}\sum_{j=1, j\neq i}^{n}\binom{N(i,j)}{2}$$ for small values of n and e under the hypothesis that all agreements of the experts are due to chance.
- For large values of n and e, Kendall (1962) developed the statistic

$$u' = \frac{4\left[\sum_{i=1}^{n}\sum_{j=1, j\neq i}^{n}\binom{N(i,j)}{2} - \binom{e}{2}\binom{n}{2}\left(\frac{e-3}{2}\right)/(e-2)\right]}{e-2}$$

which is chi-squared, df = $n!e(e-1)/[2!(n-2)!(e-2)^2]$

- The hypothesis that all agreements are due to chance should be rejected at the 5% level of significance

OVERVIEW
BRADLEY-TERRY MODEL

- Assumes that the true "value" of object i is h_i
- If experts can be treated as independent samples for each question then the probability that object i is preferred to object j is expressed as $p_{ij} = h_i / (h_i + h_j)$
- Given that i and j are compared e times, the probability of seeing i preferred to j exactly ***N(i,j)*** times, i,j = 1,...k, i < j; is

$$L = \prod_{i<j} \binom{e}{N(i,j)} p_{ij}^{\,N(i,j)} (1 - p_{ij})^{e-N(i,j)} = \prod_{i<j} \binom{e}{N(i,j)} \left(\frac{h_i}{h_i + h_j} \right)^{N(i,j)} \left(\frac{h_j}{h_i + h_j} \right)^{e-N(i,j)}$$

- Find h_i through maximum likelihood estimation

OVERVIEW
BRADLEY-TERRY MODEL

- Note that the values can be determined up to a constant, that is if h_i are solutions so are Ch_i
- Ford (1957): The following iterative solution procedure can be used to solve for the h_i up to a scale constant **provided that it is not possible to separate the n objects into two sets where all experts deem that no object in the first set is more preferable than any object in the second set.** Letting *N(i)* denote the number of times some expert prefers E_i over any other item.

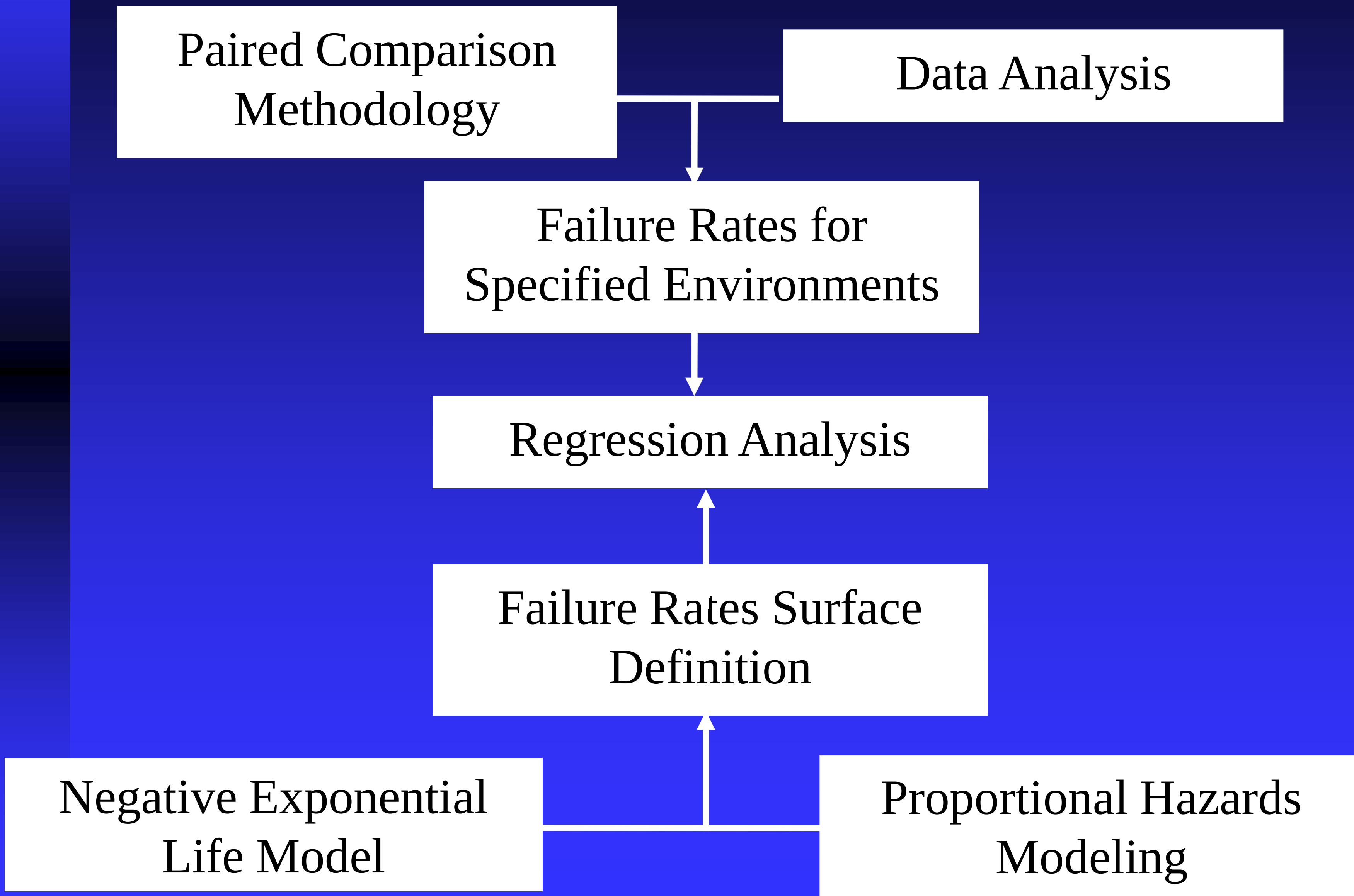
$$h_i^{(k+1)} = \frac{N(i)/e}{\sum_{j=1}^{i-1}\left[h_i^{(k)} + h_j^{(k+1)}\right]^{-1} + \sum_{j=i+1}^{n}\left[h_i^{(k)} + h_j^{(k)}\right]^{-1}}$$

OVERVIEW
NEL MODEL Cooke (1991)

- But the Bradley-Terry Model is for probabilities not failure rates!
- Note if $T_i \sim exp(\lambda_i)$ then $Pr\{T_i < T_j\} = \lambda_i/(\lambda_i+\lambda_j)$
- Thus instead of asking experts "which object do you prefer", we can ask "given two environments which environment will produce a failure first" and use all the paired comparison and Bradley-Terry Methodology
- Given that the values $h_1, \ldots, h_n$ are failure rates obtained to within a scale constant, if we can, from another method, determine an exact estimate of one of the failure rates, say h_j^+, we may calculate estimates as

$$h_i^+ = (h_j^+/h_j)*h_i \qquad i=1, \ldots, n$$

OVERVIEW OF APPROACH



DEFINE THE ENVIRONEMENT: ENVIRONMENTAL VARIABLES

		Levels		
Variables	1	**2**	**3**	**4**
Wire Guage	4\0-8 awg	10-16 awg	18-22 awg	24-26 awg
Conductor Type	Aluminum	Copper	High Streng. Copper Alloy	
Splices	None	Environmental	Non-environmental	
Bundle Protection	Some Level of Protection	Not Protected (Open)	Protected Metal Conduit	
Curvature of Bundle	Low (> 10x)	High (<= 10x)		
Ops/Main Traffic	Low	Moderate	High	
Vibration	Low	Moderate	High	Extreme
Ops temp\presurization	Benign (P&T Controlled)	D1- P Contrl. but not T	D2 (P&T not controlled)	D3 (High T, P not contrl)
Exp Corrosive Fluid	No	Yes		
Exp Conducting Fluid	No	Yes		
Bundle Size	Large (> 1.25 in)	Moderate (0.5-1.25 in)	Small (0.2-0.5 in)	Very Small (< 0.2 in)
Insulation Type	Polyimide	Hybrid (PI/FP Composite)	ETFE & other FPs	
Bundle Orientation (Shock)	Horizontal/Vertical Wire	Longitudinal		

- an upper bound of 4*3*3*….*2 = 995,328 environments

Note that these are categorical

QUANTIFY VARIABLES

- Define environments via explanatory variables

EFFECT OF SINGLE VARIABLES ON OPEN FAILURES

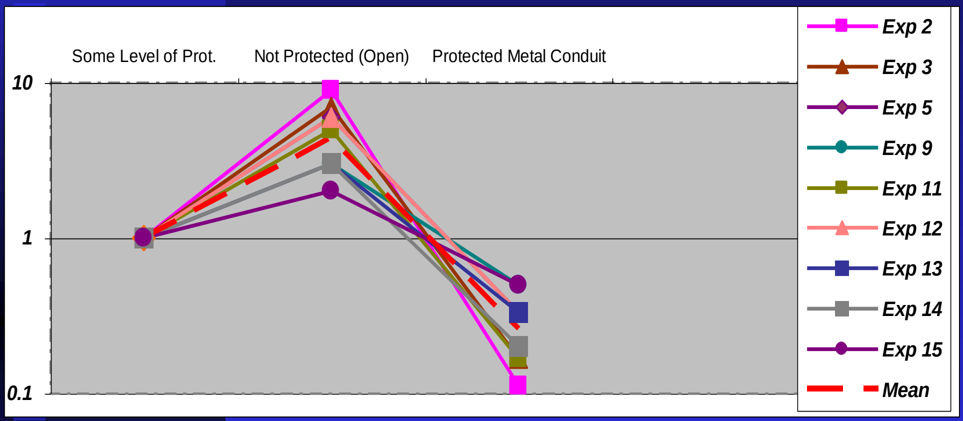
Page 2

BUNDLE PROPERTIES

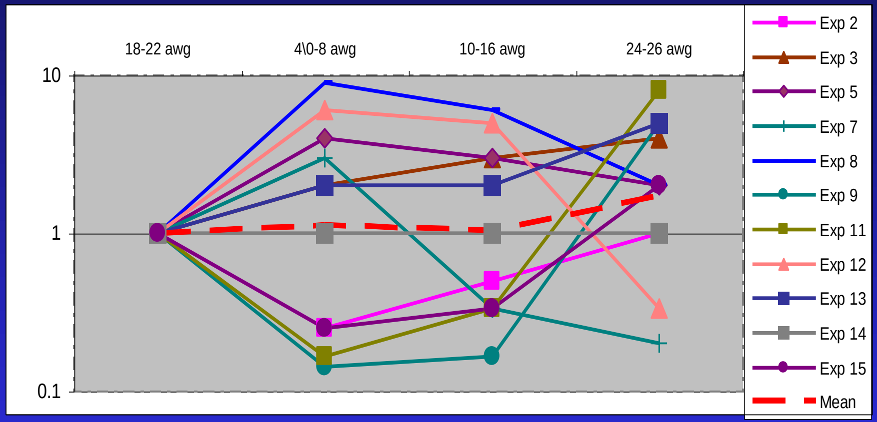
Bundle Size																	
Large (> 1.25 in)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
	less severe					<----------------				--------------->			more severe				
Moderate (0.5-1.25 in)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Small (0.2-0.5 in)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Very Small (< 0.2 in)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Bundle Protection																	
Some Level of Prot.	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
	less severe					<----------------				--------------->			more severe				
Not Protected (Open)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Curvature of Bundle																	
Low (> 10x)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
	less severe					<----------------				--------------->			more severe				
High (<= 10x)	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
Bundle Orientation (Shock)																	
Horizontal/Vertical Wire	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9
	less severe					<----------------				--------------->			more severe				
Longitudinal	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9

QUANTIFY VARIABLES

Open Failures Bundle Protection



Shorting Failures Wire Guage



$$geom\ mean(y_1,\dots,y_n) = \prod_{i=1}^{n} \left(y_n\right)^{1/n}$$

Use geometric mean as average expert response

SELECTION OF PAIRED COMPARISON ENVIRONMENTS

- This selection should
  - be relatively small
    - but at a minimum of one plus the number of variables describing the environment
  - not contain any obviously dominated environments
  - provides maximum coverage for the regression estimates
  - contain at least one environment for which failure data exists.
- However, the result should yield a relatively easy paired comparison of the environments

PAIRED COMPARISON ENVIRONMENTS

Environment	Wire Guage	Insulation Type	Conductor Type	Splices	Bundle Size	Bundle Protection	Curvature of Bundle	Bundle Orientationt.	Ops/Main Traffic	Ops temp/altitude	Vibration	Exp Corrosive Fluid	Exp Conducting Fluid
1	18-22 awg	Hybrid (PI/FP Composite)	Copper	None	Moderate (0.5-1.25 in)	Not Protected (Open)	Low (> 10x)	Horizontal/Vertical Wire	High	Benign (P&T Controlled)	Moderate	No	Yes
2	24-26 awg	Hybrid (PI/FP Composite)	High Streng. Copper Alloy	None	Very Small (< 0.2 in)	Not Protected (Open)	Low (> 10x)	Horizontal/Vertical Wire	High	Benign (P&T Controlled)	Moderate	No	Yes
3	24-26 awg	Hybrid (PI/FP Composite)	Copper	None	Moderate (0.5-1.25 in)	Not Protected (Open)	Low (> 10x)	Horizontal/Vertical Wire	Moderate	Benign (P&T Controlled)	Moderate	No	Yes
4	18-22 awg	Hybrid (PI/FP Composite)	Copper	None	Moderate (0.5-1.25 in)	Some Level of Prot.	Low (> 10x)	Horizontal/Vertical Wire	High	Benign (P&T Controlled)	High	No	Yes
5	18-22 awg	Hybrid (PI/FP Composite)	Copper	None	Large (> 1.25 in)	Not Protected (Open)	Low (> 10x)	Horizontal/Vertical Wire	High	Benign (P&T Controlled)	Moderate	Yes	Yes
6	18-22 awg	Hybrid (PI/FP Composite)	Copper	Non-environmental	Moderate (0.5-1.25 in)	Not Protected (Open)	Low (> 10x)	Horizontal/Vertical Wire	High	Benign (P&T Controlled)	Low	No	Yes
7	18-22 awg	ETFE & other FPs	Copper	None	Moderate (0.5-1.25 in)	Not Protected (Open)	Low (> 10x)	Horizontal/Vertical Wire	High	Benign (P&T Controlled)	Low	No	Yes
8	18-22 awg	Hybrid (PI/FP Composite)	Copper	None	Moderate (0.5-1.25 in)	Not Protected (Open)	High (<= 10x)	Horizontal/Vertical Wire	High	Benign (P&T Controlled)	Moderate	No	No
9	18-22 awg	Hybrid (PI/FP Composite)	Copper	None	Moderate (0.5-1.25 in)	Some Level of Prot.	Low (> 10x)	Horizontal/Vertical Wire	High	D2 (P&T not controlled)	Moderate	No	Yes
10	18-22 awg	Hybrid (PI/FP Composite)	Copper	None	Moderate (0.5-1.25 in)	Not Protected (Open)	High (<= 10x)	Horizontal/Vertical Wire	High	Benign (P&T Controlled)	Low	No	Yes
11	18-22 awg	Hybrid (PI/FP Composite)	Copper	None	Moderate (0.5-1.25 in)	Not Protected (Open)	Low (> 10x)	Longitudinal	High	Benign (P&T Controlled)	Moderate	No	No
12	18-22 awg	Hybrid (PI/FP Composite)	Copper	None	Moderate (0.5-1.25 in)	Not Protected (Open)	Low (> 10x)	Horizontal/Vertical Wire	Low	Benign (P&T Controlled)	High	No	Yes
13	18-22 awg	Polyimide	Copper	None	Moderate (0.5-1.25 in)	Not Protected (Open)	High (<= 10x)	Horizontal/Vertical Wire	High	Benign (P&T Controlled)	Moderate	No	Yes
14	4\0-8 awg	Hybrid (PI/FP Composite)	Aluminum	None	Moderate (0.5-1.25 in)	Not Protected (Open)	Low (> 10x)	Horizontal/Vertical Wire	High	Benign (P&T Controlled)	Moderate	No	No
15	4\0-8 awg	Hybrid (PI/FP Composite)	Copper	None	Moderate (0.5-1.25 in)	Not Protected (Open)	Low (> 10x)	Horizontal/Vertical Wire	High	D2 (P&T not controlled)	Moderate	No	Yes

$$\binom{15}{2} = \mathbf{105}\ \text{comparisons}$$

PAIRED COMPARISON SURVEY

Variables

Wire Guage
Conductor Type
Splices
Bundle Protection
Curvature of Bundle
Ops/Main Traffic
Vibration
Ops Temp/Presssurization
Exp Corrosive Fluid
Exp Conducting Fluid
Bundle Size
Insulation Type
Bundle Orientation

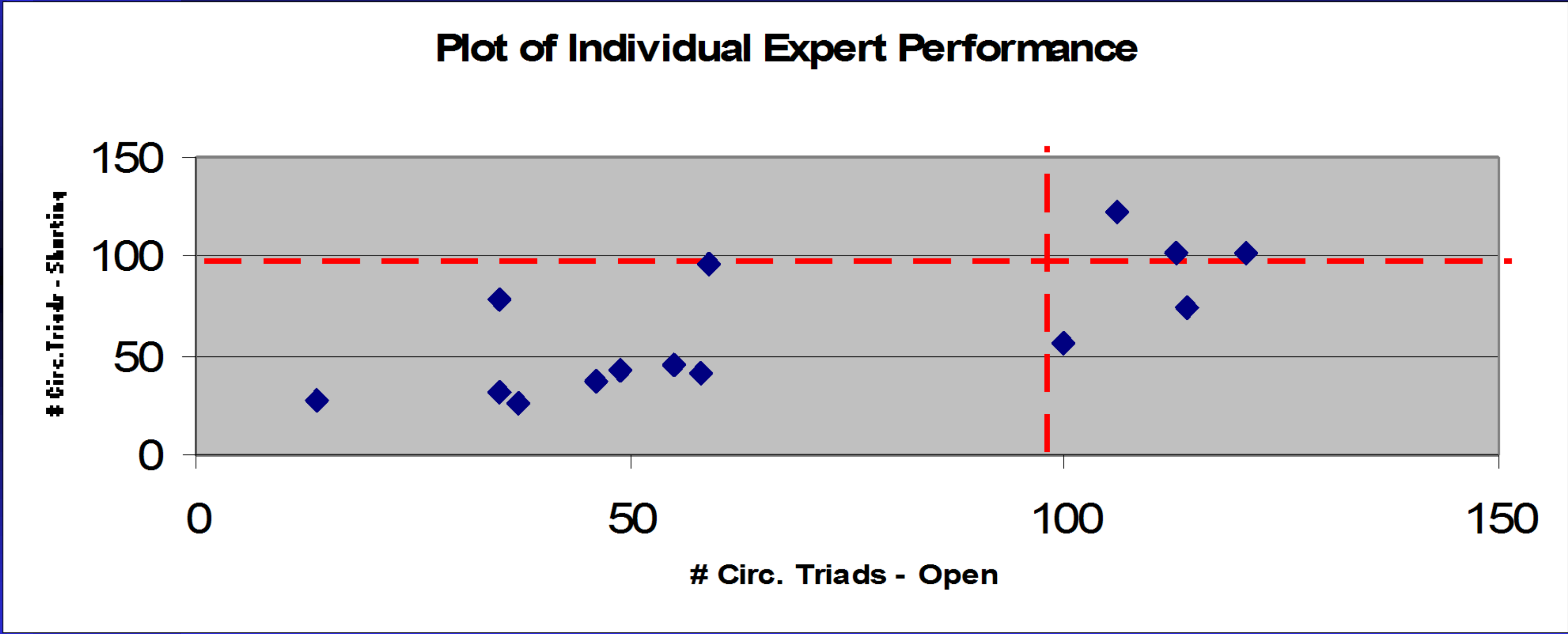
Wire Properties
Bundle Properties
Zonal Properties

PAIRED COMPARISON SURVEY

COMPARISON 11

WIRE ENVIRONMENT 1		WIRE ENVIRONMENT 2	
WIRE PROPERTIES		**WIRE PROPERTIES**	
Wire Gauge	18-22 awg	Wire Gauge	
Conductor Type	Copper	Conductor Type	
Insulation Type	Hybrid (PI/FP Composite)	Insulation Type	
Splices	None	Splices	
BUNDLE PROPERTIES		**BUNDLE PROPERTIES**	
Bundle Size	Moderate (0.5-1.25 in)	Bundle Size	
Bundle Protection	Not Protected (Open)	Bundle Protection	Some Level of Pro
Curvature of Bundle	Low (> 10x)	Curvature of Bundle	
Bundle Orientation (Shock)	Horizontal/Vertical Wire	Bundle Orientation (Shock)	
ZONAL PROPERTIES		**ZONAL PROPERTIES**	
Ops/Main Traffic	High	Ops/Main Traffic	
Ops Temp/Alt	Benign (P&T Controlled)	Ops Temp/Alt	
Vibration	Moderate	Vibration	High
Exposure to Corrosive Fluid	No	Exposure to Corrosive Fluid	
Exposure to Conductive Fluid	Yes	Exposure to Conductive Fluid	

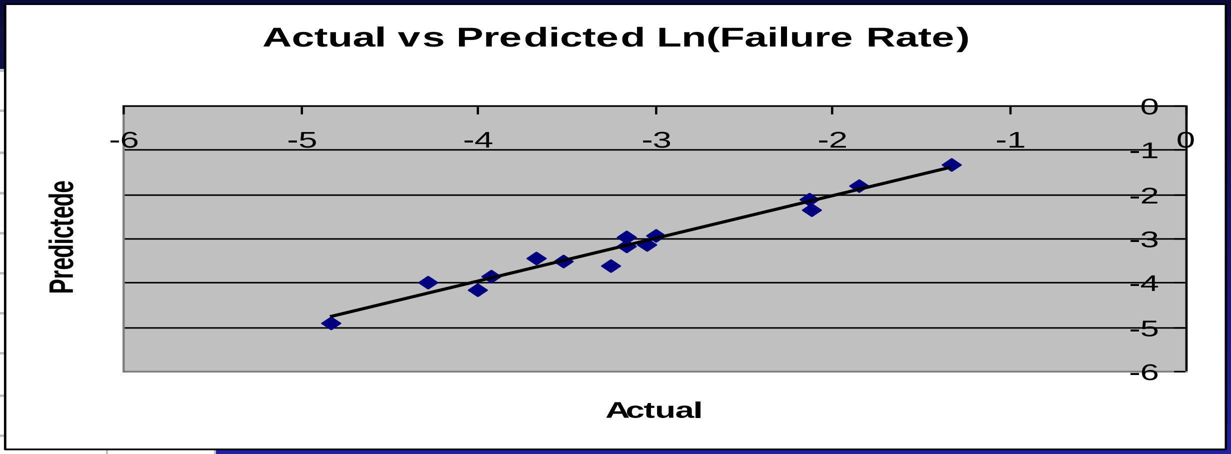
PAIRED COMPARISON RESULTS



PAIRED COMPARISON RESULTS

	Open Failures			Shorting Failures		
Environemnt	lower	Bradley-Terry Est	upper	lower	Bradley-Terry Est	upper
1	0.016	0.039	0.068	0.020	0.045	0.067
2	0.060	0.121	0.260	0.047	0.085	0.160
3	0.007	0.026	0.047	0.007	0.019	0.039
4	0.017	0.042	0.073	0.031	0.070	0.130
5	0.068	0.119	0.190	0.077	0.150	0.220
6	0.150	0.265	0.420	0.057	0.102	0.170
7	0.004	0.014	0.029	0.006	0.017	0.032
8	0.021	0.050	0.089	0.012	0.028	0.044
9	0.018	0.042	0.063	0.030	0.059	0.110
10	0.019	0.048	0.080	0.019	0.044	0.075
11	0.004	0.020	0.040	0.003	0.012	0.022
12	0.005	0.018	0.041	0.007	0.024	0.038
13	0.110	0.158	0.260	0.160	0.252	0.430
14	0.001	0.008	0.018	0.004	0.012	0.019
15	0.010	0.030	0.055	0.047	0.081	0.120

REGRESSION OUTPUT



SUMMARY OUTPUT OPEN FAILURE ANALYSIS

Regression Statistics	
Multiple R	0.9987
R Square	0.9975
Adjusted R Square	0.7929
Standard Error	0.2868
Observations	15

ANOVA

	df	*SS*	*MS*	*F*	*ignificance F*
Regression	10	161.4031	16.1403	196.2824	0.0001
Residual	5	0.4112	0.0822		
Total	15	161.8142			

	Coefficients	*tandard Err*	*t Stat*	*P-value*
Intercept	0	#N/A	#N/A	#N/A
Wire Guage	0.4535	0.1343	3.3770	0.0197
Insulation Type	2.0738	0.6439	3.2209	0.0234
Conductor Type	-0.4380	0.1701	-2.5745	0.0498
Splices	0.5639	0.0781	7.2246	0.0008
Curvature of Bundle	0.5013	0.2000	2.5061	0.0541
Shock Dam. Pot.	-8.1221	0.9121	-8.9051	0.0003
Ops/Main Traffic	0.2014	0.0560	3.5950	0.0156
Ops temp\altitude	0.2050	0.1236	1.6585	0.1581
Vibration	0.2239	0.0924	2.4218	0.0600
Exp Corrosive Fluid	0.4742	0.1026	4.6237	0.0057

Failure Rate Open Failures
= exp{0-(-3.1354)+0.4535*Wire Gauge Code
+ 2.0738*Insulation Type Code
– 0.4380*Conductor Type Code
+ 0.5639*Splices Code
+ 0.5013*Curvature of Bundle Code
- 8.1221*Shcok Damage Potential Code
+ 0.2014*Ops/Main Traffic Code
+ 0.2050*Ops Temp/Altitude
+ 0.2239*Vibration Code
+ 0.4742*Exp Corrosive Fluid Code}
$x10^{-7}$ failures per 100 feet of wire

CALCULATION OF SCALE CONSTANT CABIN LIGHTING WIRING

Report Number	Occurrence Date	Submitter	Operator	Stage of Operation	SDR Type	Report Status	ATA System Code	ATA System	Aircraft Make Name	Aircraft Model Name	Aircraft Series Name	Registration Nbr	Aircraft Serial Nbr
2002021200040	25-dec-01	AIR CARRIER\TAXI(	AMERICAN AIRLINES	INSP/MAINT	A	CLOSED (	3397	LIGHT SY:	BOEING	767	300	390AA	27450
2002021200041	25-dec-01	AIR CARRIER\TAXI(	AMERICAN AIRLINES	CRUISE	A	CLOSED (	2612	FIRE DET	BOEING	767	300	386AA	27060
2002021200034	21-dec-01	AIR CARRIER\TAXI(	AMERICAN AIRLINES	INSP/MAINT	A	CLOSED (	3397	LIGHT SY:	BOEING	767	300	378AN	25447
2002021200035	21-dec-01	AIR CARRIER\TAXI(	AMERICAN AIRLINES	INSP/MAINT	A	CLOSED (	3397	LIGHT SY:	BOEING	767	300	386AA	27060
2002021200027	20-dec-01	AIR CARRIER\TAXI(	AMERICAN AIRLINES	INSP/MAINT	A	CLOSED (	3397	LIGHT SY:	BOEING	767	300	390AA	27450
2002011100057	10-dec-01	AIR CARRIER\TAXI(	AMERICAN AIRLINES	INSP/MAINT	A	CLOSED (	3397	LIGHT SY:	BOEING	767	300	362AA	24043
2002011000070	07-dec-01	AIR CARRIER\TAXI(	AMERICAN AIRLINES	INSP/MAINT	A	CLOSED (	3397	LIGHT SY:	BOEING	767	300	353AA	24034
2002011000072	05-dec-01	AIR CARRIER\TAXI(	AMERICAN AIRLINES	INSP/MAINT	A	CLOSED (	3397	LIGHT SY:	BOEING	767	300	386AA	27060

CALCULATION OF SCALE CONSTANT

Number of Engines	Wing Type	Part Name	Part Condition	Part Location	Nature of Condition	Precautionary Condition
2	MONOPLANE-LOW WING	WIRE	DAMAGEI	CABIN	SYSTEM 1	NONE
2	MONOPLANE-LOW WING	WIRE	FALSE INI	LAVATOR	FALSE W/	UNSCHED LAN
2	MONOPLANE-LOW WING	WIRE	DAMAGEI	CABIN	SYSTEM 1	NONE
2	MONOPLANE-LOW WING	WIRE	DAMAGEI	CABIN	SYSTEM 1	NONE
2	MONOPLANE-LOW WING	WIRE	BROKEN	CABIN	SYSTEM 1	NONE
2	MONOPLANE-LOW WING	WIRE	DAMAGEI	CABIN	SYSTEM 1	NONE
2	MONOPLANE-LOW WING	WIRE	DAMAGEI	CABIN	SYSTEM 1	NONE
2	MONOPLANE-LOW WING	WIRE	BROKEN	CABIN	SYSTEM 1	NONE

CALCULATION OF SCALE CONSTANT

TURBOFAN/TURBOJET			......OCTOBER......		.....NOVEMBER......		.....DECEMBER......		.......Quarter.......	
Aircraft Mfg	Model	Operator Designator	Number Aircraft	Flight Time	Number Aircraft	Flight Time	Number Aircraft	Flight Time	Average Number Aircraft	Total Flight Time
A	A300*	FDEA	43	5,382	43	5,394	43	5,990	43	16,766
	Aircraft Model Total:		43	5,382	43	5,394	43	5,990	43	16,766
A	A300B4203	DHLA			6	811			6	811
		XNOA					8	1,299	8	1,299
	Aircraft Model Total:				6	811	8	1,299	7	2,110
A	A300B4605R	AALA	34	5,909	34	6,409	34	6,852	34	19,170
	Aircraft Model Total:		34	5,909	34	6,409	34	6,852	34	19,170
A	A300F4605R	IRXA	47	4,250	47	4,875	47	6,246	47	15,371
	Aircraft Model Total:		47	4,250	47	4,875	47	6,246	47	15,371
A	A310203	FDEA	26	2,141	26	2,240	26	3,209	26	7,590
	Aircraft Model Total:		26	2,141	26	2,240	26	3,209	26	7,590
A	A310222	FDEA	18	1,489	18	1,711	18	1,798	18	4,998

OTHER WORKS

Chaloner, K., Church, T., Louis, T. A., and Matts, J.P., (1993), “Graphical elicitation of a prior distribution for a clinical trial”, Statistician, 42, pp. 341-355

Zuashkiani, A., Banjevic, D. and Jardine, A.K.S. (2009), “Estimating parameters of the proportional hazards modelbased on expert knowledge and statistical data”, Journal of n the Operational Research Society, 60, pp. 1621-1636.